



# **Radar Cross-Section (RCS) Measurements of a Dismount with Rocket-Propelled Grenade (RPG) Launcher at Ka-Band**

**by Suzanne R. Stratton and Robert L. Bender**

**ARL-TR-3855**

**July 2006**

## **NOTICES**

### **Disclaimers**

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

# **Army Research Laboratory**

Aberdeen Proving Ground, MD 21005

---

**ARL-TR-3855****July 2006**

---

## **Radar Cross-Section (RCS) Measurements of a Dismount with Rocket-Propelled Grenade (RPG) Launcher at Ka-Band**

**Suzanne R. Stratton and Robert L. Bender**  
Sensors and Electron Devices Directorate, ARL

<b>REPORT DOCUMENTATION PAGE</b>			<i>Form Approved</i> <i>OMB No. 0704-0188</i>	
<p>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p> <p><b>PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</b></p>				
<b>1. REPORT DATE (DD-MM-YYYY)</b> July 2006		<b>2. REPORT TYPE</b> Final		<b>3. DATES COVERED (From - To)</b> 6 to 18 August 2003
<b>4. TITLE AND SUBTITLE</b>  Radar Cross-Section (RCS) Measurements of a Dismount with Rocket-Propelled Grenade (RPG) Launcher at Ka-Band			<b>5a. CONTRACT NUMBER</b>	
			<b>5b. GRANT NUMBER</b>	
			<b>5c. PROGRAM ELEMENT NUMBER</b>	
<b>6. AUTHOR(S)</b>  Suzanne R. Stratton and Robert L. Bender			<b>5d. PROJECT NUMBER</b>	
			<b>5e. TASK NUMBER</b>	
			<b>5f. WORK UNIT NUMBER</b>	
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b> U.S. Army Research Laboratory ATTN: AMSRD-ARL-SE-RM Aberdeen Proving Ground, MD 21005			<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>  ARL-TR-3855	
<b>9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b> U.S. Army Research Laboratory Aberdeen Proving Ground, MD 21005			<b>10. SPONSOR/MONITOR'S ACRONYM(S)</b>	
			<b>11. SPONSOR/MONITOR'S REPORT NUMBER(S)</b>	
<b>12. DISTRIBUTION/AVAILABILITY STATEMENT</b> Approved for public release; distribution unlimited.				
<b>13. SUPPLEMENTARY NOTES</b>				
<b>14. ABSTRACT</b>  The U.S. Army Research Laboratory's (ARL's) Radio Frequency and Electronics Division sponsored and conducted a series of measurements to characterize the millimeter wave (MMW) signatures of one Soldier carrying a rocket-propelled grenade (RPG) launcher with grenade at 34 GHz over three depression angles and for three different body postures: prone, kneeling, and standing. The measurements were taken by ARL at its outdoor signature research facility at Aberdeen Proving Ground, MD, on 6 through 18 August 2003. A statistical summary of the measurements is presented in this report, along with a full set of radar cross section (RCS) plots of the measurements for four linear polarization combinations. Measurements of the Soldier holding an RPG launcher show that the mean RCS of the target decreases with decreasing body profile over all depression angles. The mean RCS does not depend on launcher angle or depression angle in most cases. The co-polarized means are much more sensitive than the cross-polarized terms to changes in body posture and launcher angle. The RPG launcher contributes the largest component to the signature.				
<b>15. SUBJECT TERMS</b> Radar cross-section, millimeter wave, rocket propelled grenade launcher				
<b>16. SECURITY CLASSIFICATION OF:</b>			<b>17. LIMITATION OF ABSTRACT</b>  SAR	<b>18. NUMBER OF PAGES</b>  56
<b>a. REPORT</b> Unclassified	<b>b. ABSTRACT</b> Unclassified	<b>c. THIS PAGE</b> Unclassified		
			<b>19b. TELEPHONE NUMBER (Include area code)</b> (410) 278-3942	

---

## Contents

---

<b>List of Figures</b>	<b>iv</b>
<b>List of Tables</b>	<b>v</b>
<b>Acknowledgments</b>	<b>vii</b>
<b>1. Introduction</b>	<b>1</b>
<b>2. Instrumentation Description</b>	<b>1</b>
<b>3. Test Setup and Procedures</b>	<b>3</b>
<b>4. Data Collected</b>	<b>5</b>
<b>5. Summary</b>	<b>9</b>
<b>6. References</b>	<b>10</b>
<b>Appendix A. Logbook Synopsis</b>	<b>11</b>
<b>Appendix B. Polar Plots</b>	<b>15</b>
<b>Distribution List</b>	<b>45</b>

---

## List of Figures

---

Figure 1. Measurement setup at air base range 8, APG, MD. ....	2
Figure 2. Close view of RPG launcher used in measurements at air base range 8. ....	5
Figure 3. ISAR image of man standing (a) with and (b) without the RPG launcher at 2-degree depression angle, 0-degree RPG angle and 90-degree turntable angle. ....	8
Figure 4. ISAR image of man prone (a) with and (b) without the RPG launcher at 2-degree depression angle, 0-degree RPG angle and 90-degree turntable angle. ....	8
Figure B-1. RCS plots for trial TGT77AF, 2-degree depression, 0-degree RPG angle, man standing. ....	16
Figure B-2. RCS plots for trial TGT77AG, 2-degree depression, 0-degree RPG angle, man standing facing aft. ....	17
Figure B-3. RCS plots for trial TGT77AH, 2-degree depression, RPG angle 0-degree, man kneeling facing aft. ....	18
Figure B-4. RCS plots for trial TGT77AI, 2-degree depression, 0-degree RPG angle, man prone facing aft. ....	19
Figure B-5. RCS plots for trial TGT77AJ, 2-degree depression, 90-degree RPG angle, man standing facing aft. ....	20
Figure B-6. RCS plots for trial TGT77AK, 2-degree depression, man without RPG kneeling facing aft. ....	21
Figure B-7. RCS plots for trial TGT77AQ, 2-degree depression, 22.5-degree RPG angle, man standing facing aft. ....	22
Figure B-8. RCS plots for trial TGT77AR, 2-degree depression, 22.5-degree RPG angle, man kneeling facing aft. ....	23
Figure B-9. RCS plots for trial TGT77AS, 2-degree depression, man without RPG standing facing aft. ....	24
Figure B-10. RCS plots for trial TGT77AT, 2-degree depression, 45-degree RPG angle, man standing facing aft. ....	25
Figure B-11. RCS plots for trial TGT77AV, 2-degree depression, man without RPG, prone facing aft. ....	26
Figure B-12. RCS plots for trial TGT77BM, 5-degree depression, 0-degree RPG angle, man standing facing aft. ....	27
Figure B-13. RCS plots for trial TGT77BN, 5-degree depression, 0-degree RPG angle, man kneeling facing aft. ....	28
Figure B-14. RCS plots for trial TGT77BO, 5-degree depression, 0-degree RPG angle, man prone facing aft. ....	29
Figure B-15. RCS plots for trial TGT77BP, 5-degree depression, 90-degree RPG angle, man standing facing aft. ....	30

Figure B-16. RCS plots for trial TGT77BQ, 5-degree depression, man standing without RPG facing aft. ....	31
Figure B-17. RCS plots for trial TGT77BW, 5-degree depression, 22.5-degree RPG angle, man standing facing aft. ....	32
Figure B-18. RCS plots for trial TGT77BX, 5-degree depression, 22.5-degree RPG angle, man kneeling facing aft. ....	33
Figure B-19. RCS plots for trial TGT77CD, 5-degree depression, man without RPG kneeling facing aft. ....	34
Figure B-20. RCS plots for trial TGT77CE, 5-degree depression, 45-degree RPG angle, man standing facing aft. ....	35
Figure B-21. RCS plots for trial TGT77CF, 5-degree depression, 45-degree RPG angle, man kneeling facing aft. ....	36
Figure B-22. RCS plots for trial TGT77CG, 5-degree depression, man without RPG prone facing aft. ....	37
Figure B-23. RCS plots for trial TGT77CM, 15-degree depression, 0-degree RPG angle, man standing facing aft. ....	38
Figure B-24. RCS plots for trial TGT77CN, 15-degree depression, 0-degree RPG angle, man kneeling facing aft. ....	39
Figure B-25. RCS plots for trial TGT77CO, 15-degree depression, 0-degree RPG angle, man prone facing aft. ....	40
Figure B-26. RCS plots for trial TGT77DA, 15-degree depression, 22.5-degree RPG angle, man standing facing aft. ....	41
Figure B-27. RCS plots for trial TGT77DB, 15-degree depression, 22.5-degree RPG angle, man kneeling facing aft. ....	42
Figure B-28. RCS plots for trial TGT77DC, 15-degree depression, man without RPG kneeling facing aft. ....	43
Figure B-29. RCS plots for trial TGT77DD, 2-degree depression, 45-degree RPG angle, man kneeling facing aft. ....	44

---

## List of Tables

Table 1. Radar characteristics. ....	2
Table 2. Test matrix. ....	3
Table 3a. RCS summary statistics for the man with RPG at 2-degrees depression angle for VV polarization in dBsm. ....	6
Table 3b. RCS summary statistics for the man with RPG at 5-degree depression angle for VV polarization in dBsm. ....	6

Table 3c. RCS summary statistics for the man with RPG at 15-degree depression angle for VV polarization in dBsm. ....	6
Table 4a. Mean RCS for four linear polarizations in dBsm, depression angle 2 degrees. ....	7
Table 4b. Mean RCS for four linear polarizations in dBsm, depression angle 5 degrees. ....	7
Table 4c. Mean RCS for four linear polarizations in dBsm, depression angle 15 degrees. ....	7



---

## **Acknowledgments**

---

The authors wish to acknowledge Donald Testerman, SEDD/ARL, for his able assistance in setting up and documenting the targets and in conducting the measurements.

INTENTIONALLY LEFT BLANK.

---

## **1. Introduction**

---

There is much interest today in the detection and classification of troop dismounts in a variety of environments. Before detection and classification algorithms can be developed, a basic understanding of the signature associated with a single dismount must be acquired. The U.S. Army Research Laboratory (ARL) has a triband millimeter wave (MMW) polarimetric inverse synthetic aperture radar (ISAR) that is used for a broad range of MMW research, including target signature measurements. High-resolution radar cross section (RCS) measurements of a dismount taken with this equipment can be used in computer simulations that combine this information with data about various types of environmental background to assist in the radar hardware and waveform design process for detection optimization and to test classification algorithms.

ARL's Radio Frequency and Electronics Division sponsored a series of measurements to characterize the MMW signature of a man holding a rocket-propelled grenade (RPG) launcher with (inert) grenade at 34 GHz over three depression angles and for three body positions. The measurements were made by ARL at its outdoor signature research facility at Aberdeen Proving Ground (APG), MD, over the two-week period of 6 through 18 August 2003. A statistical summary of the measurements is presented in this report, along with the full set of RCS plots of the measurements for linear polarizations.

---

## **2. Instrumentation Description**

---

The 34-GHz fully polarimetric instrumentation radar at the ARL signature research facility was used to collect the data. The radar uses a stepped frequency waveform. A listing of the important system parameters at Ka-Band is given in table 1, while a full description of the operation of the radar and data acquisition system is presented in ARL-TR-1421 (Stratton et al., 1997).

Table 1. Radar characteristics.

Parameter	Ka-Band
Center frequency	34.0 GHz
RF bandwidth	1599.359 MHz
Frequency step	6.272 MHz
Peak transmitted power	+17 dBm
Pulse width	100 ns
Pulse repetition frequency	1.0 MHz
Transmitted polarization	V and H
Received polarization	V and H
3-dB beam width (one way)	8.5°
System noise figure	5.4 dB SSB
Polarization isolation	35 dB

Notes: V = vertical  
H = horizontal  
SSB = single sideband

Measurements made with the system are taken with the radar mounted on an elevator on a 125-ft tower. The radar is pointed at an in-ground turntable 153 ft away. The target sits on this turntable. Figure 1 shows the range setup. A television camera is boresighted with the radar and provides a video image of the target that is recorded as the target rotates. A 35-mm camera is also boresighted with the radar, and photographs are taken every 45 degrees of azimuth during the rotation. Target rotation is always counterclockwise. A complete rotation at 34 GHz takes about 10 min. A fully calibrated RCS plot can be ready 10 min after the measurement. A series of ISAR images displayed on a monitor as a “movie” is available 10 to 15 min after each measurement.

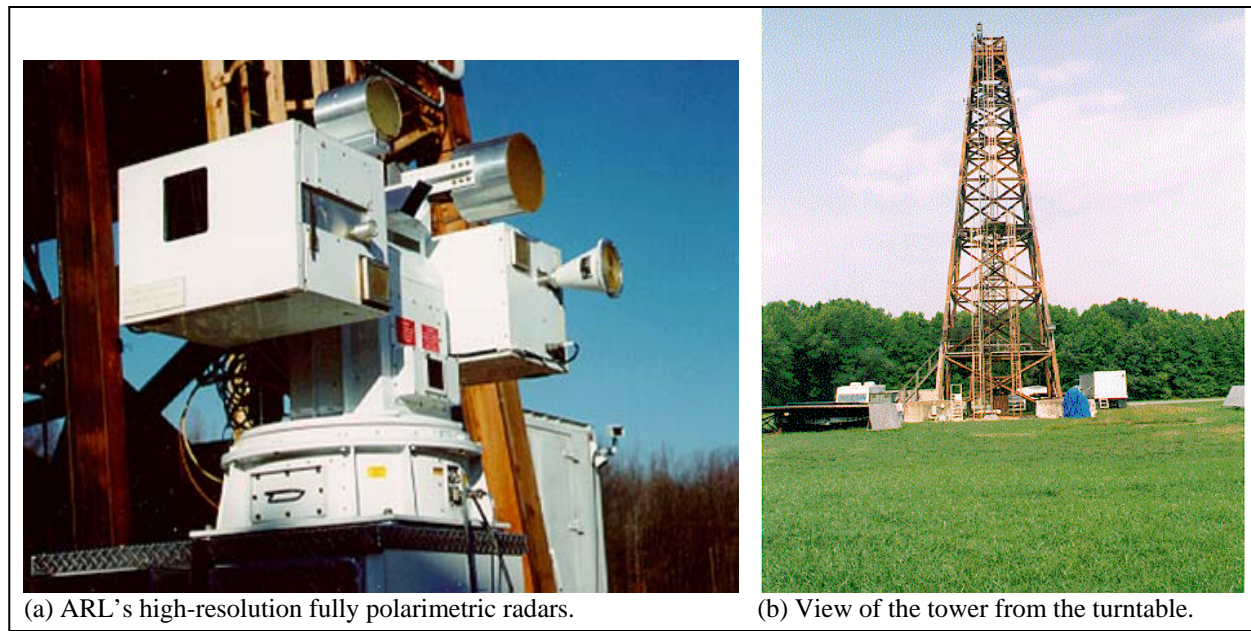


Figure 1. Measurement setup at air base range 8, APG, MD.

---

### 3. Test Setup and Procedures

---

A rocket-propelled grenade launcher and RPG-7 were delivered via the National Ground Intelligence Center (NGIC) for these signature measurements. The main objective was to characterize the RCS of the man holding the launcher and to obtain some high-quality ISAR imagery. To do this, it was also necessary to characterize the radar stability and accuracy of the measurements by measuring a calibrated reflector at each of the depression angles used in the test. The test plan called for measurements of the man at three depression angles at 34 GHz. The exact sequence of measurements is shown in table 2, along with the assigned target numbers. A complete record of the measurements and radar calibrations is in the logbook synopsis in appendix A.

Table 2. Test matrix.

Date	Datafile	RPG Angle (°)	Depression angle (°)	Body Position
August 6, 2003	TGT77AF	0	2	Standing
	TGT77AG	0	2	Standing
	TGT77AH	0	2	Kneeling
	TGT77AI	0	2	Prone
	TGT77AJ	90	2	Standing
	TGT77AK	NA	2	Kneeling
	TGT77AQ	22.5	2	Standing
	TGT77AR	22.5	2	Kneeling
	TGT77AS	NA	2	Standing
	TGT77AT	45	2	Standing
	TGT77AV	NA	2	Prone
August 12, 2003	TGT77BM	0	5	Standing
	TGT77BN	0	5	Kneeling
	TGT77BO	0	5	Prone
	TGT77BP	90	5	Standing
	TGT77BQ	NA	5	Standing
August 13, 2003	TGT77BW	22.5	5	Standing
	TGT77BX	22.5	5	Kneeling
August 14, 2003	TGT77CD	NA	5	Kneeling
	TGT77CE	45	5	Standing
	TGT77CF	45	5	Kneeling
	TGT77CG	NA	5	Prone
	TGT77CM	0	15	Standing
	TGT77CN	0	15	Kneeling
	TGT77CO	0	15	Prone
August 18, 2003	TGT77DA	22.5	15	Standing
	TGT77DB	22.5	15	Kneeling
	TGT77DC	NA	15	Kneeling
	TGT77DD	45	2	Kneeling

A trihedral corner reflector of known cross section was placed on the turntable for an initial set of measurements at the required depression angles. This provided a method to check the accuracy of the measurement process at each depression angle, which could be used to attest to the accuracy of subsequent measurements of the target. At each depression angle, the trihedral was adjusted in elevation so that the face was perpendicular to the line of sight to the antenna, providing for the maximum return. All data were calibrated in decibels relative to one square meter (dBsm). Trihedral data were collected at 34 GHz. The RCS measurements are different from the known value by no more than 0.8 dB. In another report (Stratton et al., 1997), the repeatability of measurements is shown to be less than 1 dB.

Figure 2 shows the RPG launcher that was used in the measurements at Air Base Range 8. The turntable measurements were taken at depression angles of 2, 5, and 15 degrees, with the antenna boresight aimed directly in the center of mass of the man. The body posture of the man changed from standing to kneeling to prone during the course of the measurements, and the position of the RPG launcher the man was holding changed from 0, 22.5, 45, and 90 degrees from the horizontal. During a target rotation, the radar transmitted vertical and horizontal polarizations, alternating between four vertical transmit pulses and four horizontal transmit pulses. Both vertical (V) and horizontal (H) receiver channels were recorded to provide fully polarimetric data.

The system was calibrated before and after each measurement. A detailed description of the calibration method is given in ARL-MR-318 (Bender, 1996).



(a) RPG launcher with grenade.



(b) Man kneeling with RPG launcher at 0 degrees with respect to horizontal.

Figure 2. Close view of RPG launcher used in measurements at air base range 8.

---

## 4. Data Collected

---

Table 3a shows the summary statistics taken from the plots of the target measurements for the vertical-vertical (VV) polarization combination at 34 GHz and 2-degrees depression angle, with the man turned facing aft with respect to the radar at the start of the rotation. Table 3b gives the same statistics for the measurements made at a depression angle of 5 degrees, and table 3c gives the results when the depression angle is 15 degrees.

Table 3a. RCS summary statistics for the man with RPG at 2-degrees depression angle for VV polarization in dBsm.

<b>RPG Angle (°)</b>	<b>Posture</b>	<b>Mean (dBsm)</b>	<b>Median (dBsm)</b>	<b>Standard deviation (dBsm)</b>
0	standing	-4.5	-5.2	6.9
0	standing	-4.3	-5.4	6.7
0	kneeling	-6.0	-7.2	8.0
0	prone	-9.0	-10.4	9.6
22.5	standing	-4.3	-4.8	6.7
22.5	kneeling	-6.6	-7.4	8.4
45	standing	-4.4	-5.2	6.8
45	kneeling	-5.0	-6.4	7.3
90	standing	-4.4	-4.8	6.8
No RPG	standing	-6.1	-6.6	8.0
No RPG	kneeling	-9.7	-10.4	9.9
No RPG	prone	-17.4	-17.8	12.4

Table 3b. RCS summary statistics for the man with RPG at 5-degree depression angle for VV polarization in dBsm.

<b>RPG Angle (°)</b>	<b>Posture</b>	<b>Mean (dBsm)</b>	<b>Median (dBsm)</b>	<b>Standard deviation (dBsm)</b>
0	standing	-5.2	-5.6	7.4
0	kneeling	-6.4	-7.2	8.2
0	prone	-8.0	-8.8	9.1
22.5	standing	-4.4	-5.0	6.8
22.5	kneeling	-7.0	-7.6	8.6
45	standing	-4.7	-5.2	7.0
45	kneeling	-6.1	-6.6	8.0
90	standing	-5.2	-5.6	7.4
No RPG	standing	-7.0	-7.4	8.6
No RPG	kneeling	-7.8	-8.4	9.0
No RPG	prone	-10.0	-10.8	10.0

Table 3c. RCS summary statistics for the man with RPG at 15-degree depression angle for VV polarization in dBsm.

<b>RPG Angle (°)</b>	<b>Posture</b>	<b>Mean (dBsm)</b>	<b>Median (dBsm)</b>	<b>Standard deviation (dBsm)</b>
0	standing	-5.8	-5.8	7.8
0	kneeling	-6.2	-6.2	8.1
0	prone	-6.8	-7.2	8.5
22.5	standing	-14.7	-15.0	11.7
22.5	kneeling	-15.0	-15.2	11.8
No RPG	kneeling	-14.2	-15.0	11.5

Table 4a shows the mean RCS values of the measurements for all four linear polarization combinations, 2-degree depression angle, table 4b gives the 5-degree depression angle results, and table 4c gives the 15-degree depression angle results. All the statistics were computed in square meters and then converted to a value with units of dBsm. The full set of RCS polar plots for the vehicle is shown in appendix B.



Table 4a. Mean RCS for four linear polarizations in dBsm, depression angle 2 degrees.

<b>RPG Angle (°)</b>	<b>Posture</b>	<b>TVRV (dBsm)</b>	<b>TVRH (dBsm)</b>	<b>THRV (dBsm)</b>	<b>THRH (dBsm)</b>
0	standing	-4.5	-17.1	-17.0	-4.6
0	standing	-4.3	-17.0	-17.0	-4.5
0	kneeling	-6.0	-17.2	-17.2	-6.1
0	prone	-9.0	-18.4	-18.3	-9.2
22.5	standing	-4.3	-14.9	-14.8	-4.2
22.5	kneeling	-6.6	-15.4	-15.3	-6.3
45	standing	-4.4	-15.4	-15.3	-4.4
45	kneeling	-5.0	-14.5	-14.6	-5.1
90	standing	-4.4	-17.5	-17.4	-4.6
No RPG	standing	-6.1	-19.4	-19.4	-6.0
No RPG	kneeling	-9.7	-19.9	-19.9	-9.6
No RPG	prone	-17.4	-22.9	-23.1	-17.0

Notes: TVRV = Transmit Vertical, Receive Vertical.  
 TVRH = Transmit Vertical, Receive Horizontal.  
 THRV = Transmit Horizontal, Receive Vertical.  
 THRH = Transmit Horizontal, Receive Horizontal.

Table 4b. Mean RCS for four linear polarizations in dBsm, depression angle 5 degrees.

<b>RPG Angle (°)</b>	<b>Posture</b>	<b>TVRV (dBsm)</b>	<b>TVRH (dBsm)</b>	<b>THRV (dBsm)</b>	<b>THRH (dBsm)</b>
0	standing	-5.2	-16.0	-15.8	-5.1
0	kneeling	-6.4	-16.5	-16.4	-6.4
0	prone	-8.0	-17.3	-17.2	-8.3
22.5	standing	-4.4	-14.4	-14.2	-4.5
22.5	kneeling	-7.0	-15.7	-15.5	-7.0
45	standing	-4.7	-15.5	-15.3	-4.9
45	kneeling	-6.1	-15.8	-15.6	-6.4
90	standing	-5.2	-17.3	-17.2	-5.4
No RPG	standing	-7.0	-19.3	-19.2	-6.9
No RPG	kneeling	-7.8	-17.7	-17.6	-8.1
No RPG	prone	-10.0	-19.0	-18.8	-10.6

Table 4c. Mean RCS for four linear polarizations in dBsm, depression angle 15 degrees.

<b>RPG Angle (°)</b>	<b>Posture</b>	<b>TVRV (dBsm)</b>	<b>TVRH (dBsm)</b>	<b>THRV (dBsm)</b>	<b>THRH (dBsm)</b>
0	standing	-5.8	-13.6	-13.6	-7.7
0	kneeling	-6.2	-13.8	-13.8	-8.4
0	prone	-6.8	-14.3	-14.3	-9.1
22.5	standing	-14.7	-20.9	-21.0	-16.0
22.5	kneeling	-15.0	-21.3	-21.3	-16.4
No RPG	kneeling	-14.2	-20.6	-20.6	-15.8

The range of RCS means for TVRV polarization is -4.3 to -15.0 dBsm over all depression angles and RPG angles for the man holding the RPG launcher. In general, as the body posture changes so that the profile of the man decreases (i.e., going from standing to kneeling to prone), the mean RCS decreases. For the man who is not carrying an RPG launcher, the RCS is lower

for all depression angles and postures than that of the man of corresponding body posture with RPG launcher. The angle of the launcher does not have a significant impact on the mean RCS value for the 2- and 5-degree depression angle, but there is a large change in RCS between the 0- and 22.5-degree launcher angle data for the 15-degree depression angle. The cross-polarized RCS mean values are much lower than the co-polarized means and tend to be less sensitive than the co-polarized mean values to the body posture of the man, although they also follow the general rule of decreasing as the body posture decreases.

It can be seen from the linear RCS curves that the co-polarized measurements show peaks at broadsides for the man holding the RPG launcher, whereas for the man without the launcher, there are no peaks at broadsides. Also, with the man holding the RPG launcher at 90 degrees from the horizontal, the peaks at broadsides are greatly diminished. There are no obvious features that correspond to a man without the launcher, no matter what the body position. The curves are fairly flat over these 360-degree rotations. An examination of the ISAR images for the man with and without the RPG launcher at comparable depression angles reveals that the launcher is by far the most significant part of the signature, as can be seen in figures 3 and 4.

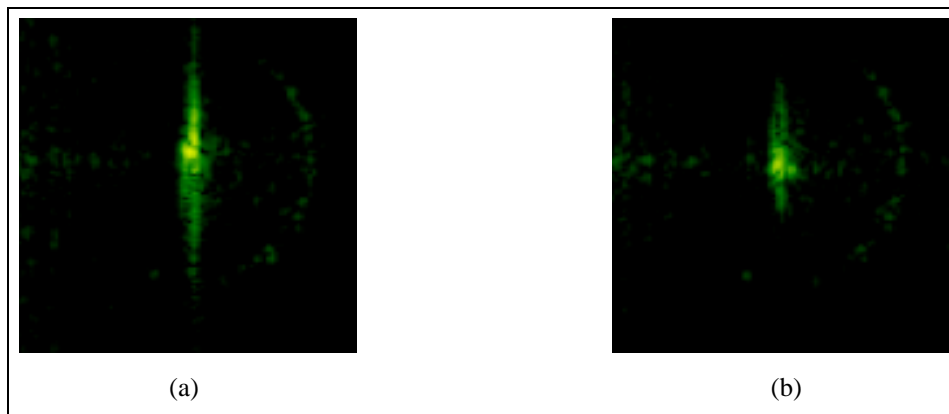


Figure 3. ISAR image of man standing (a) with and (b) without the RPG launcher at 2-degree depression angle, 0-degree RPG angle and 90-degree turntable angle.

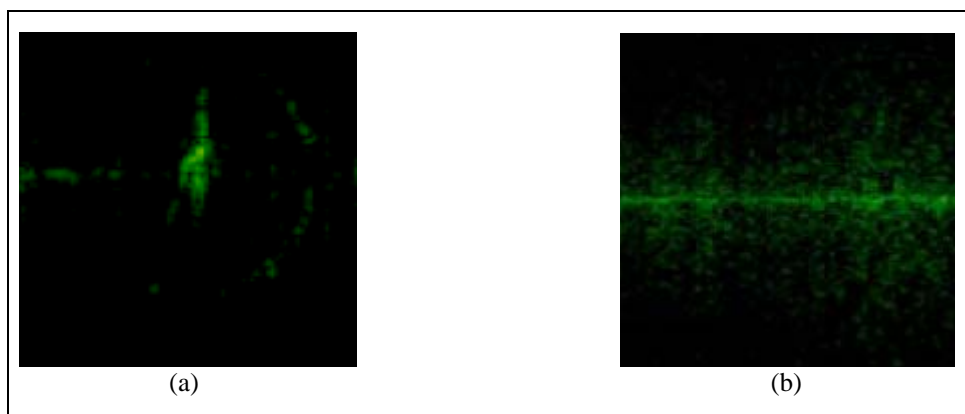


Figure 4. ISAR image of man prone (a) with and (b) without the RPG launcher at 2-degree depression angle, 0-degree RPG angle and 90-degree turntable angle.

---

## 5. Summary

---

Measurements of the man holding an RPG launcher show that the mean RCS of the target decreases with decreasing body profile over all depression angles. The mean RCS does not depend on launcher angle or depression angle except for the case of the 22.5-degree launcher angle and 15-degree depression angle. The linear RCS curves are roughly similar for the man without RPG launcher at each depression angle. The co-polarized means are much more sensitive than the cross-polarized terms to the changes in body posture and launcher angle. The RPG launcher contributes the largest component to the signature.

---

## 6. References

---

Stratton, S. R.; Wallace, H. B.; Bender, R. L.; Brodeen, A.E.M. *A Comparison of Radar Cross Section (RCS) Measurements of 11 T72M1 Tanks at 35 GHz*; ARL-TR-1421; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, July 1997.

Bender, R. L. *Use of a Remotely Controlled Dihedral for Calibrating a Polarimetric Radar*; ARL-MR-318; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, June 1996.

---

## Appendix A. Logbook Synopsis

---

8/06/03     Sunny, warm, 70's

Operators: Bob Bender  
            Tim Burcham

RPG Launcher with soldier

tgt77aa     79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns  
tgt77ab     dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77ac     dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450  
ns  
tgt77ad     dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77ae     sky @ 34 GHz @ 152 ft, gate 450 ns

tgt77af     Man with RPG standing nose on, 0 degrees RPG angle @ 2  
degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77ag     Man with RPG standing rear on, 0 degrees RPG angle @ 2  
degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77ah     Man with RPG kneeling rear on, 0 degrees RPG angle @ 2  
degrees depression @ 34 GHz @ 184 ft, gate 520 ns  
tgt77ai     Man with RPG prone, rear on, 0 degrees RPG angle @ 2  
degrees depression @ 34 GHz @ 184 ft, gate 520 ns  
tgt77aj     Man with RPG standing rear on, 90 degrees RPG angle @  
2 degrees depression @ 34 GHz @ 184 ft, gate 520 ns  
tgt77ak     Man without RPG kneeling rear on @ 2 degrees  
depression @ 34 GHz @ 184 ft, gate 520 ns

tgt77al     79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns  
tgt77am     dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77an     dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450  
ns  
tgt77ao     dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77ap     sky @ 34 GHz @ 152 ft, gate 450 ns

tgt77aq     Man with RPG standing rear on, 22.5 degrees RPG angle  
@ 2 degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77ar     Man with RPG kneeling rear on, 22.5 degrees RPG angle  
@ 2 degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77as     Man without RPG standing rear on @ 2 degrees  
depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77at     Man with RPG standing rear on, 45 degrees RPG angle @  
2 degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77au     Man with RPG kneeling rear on, 45 degrees RPG angle @  
2 degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
---corrupted data file (see tgt77dd for repeat of this

measurement)

tgt77av Man without RPG prone looking rear on @ 2 degrees  
depression @ 34 GHz @ 152 ft, gate 450 ns

tgt77aw 79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns  
tgt77ax dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77ay dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450  
ns  
tgt77az dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77ba sky @ 34 GHz @ 152 ft, gate 450 ns

8/07/03 Cloudy, cool, 70's Operators: Bob Bender  
Don Testerman

tgt77bb 79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bc dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bd dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450  
ns  
tgt77be dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bf sky @ 34 GHz @ 152 ft, gate 450 ns

tgt77bg Man standing with RPG looking rear on @ 5 degrees  
depression @ 34 GHz @ 152 ft, gate 450 ns  
missing a lot of angles. Will troubleshoot angle  
encoder and try to collect data again next week.

8/12/03 Cloudy, warm, 80's Operators: Bob Bender  
Don Testerman

tgt77bh 79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bi dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bj dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450  
ns  
tgt77bk dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bl sky @ 34 GHz @ 152 ft, gate 450 ns

tgt77bm Man standing with RPG at 0 degrees looking rear on @ 5  
degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bn Man kneeling with RPG at 0 degrees looking rear on @ 5  
degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bo Man prone with RPG at 0 degrees looking rear on @ 5  
degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bp Man standing with RPG at 90 degrees looking rear on @  
5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bq Man standing without RPG looking rear on @ 5 degrees

depression @ 34 GHz @ 152 ft, gate 450 ns

8/13/03 Cloudy, warm, 80's

Operators: Bob Bender  
Don Testerman

tgt77br 79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bs dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bt dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bu dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bv sky @ 34 GHz @ 152 ft, gate 450 ns  
  
tgt77bw Man standing with RPG at 22.5 degrees looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bx Man kneeling with RPG at 22.5 degrees looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns

8/14/03 Sunny, warm, 80's

Operators: Bob Bender  
Don Testerman

tgt77by 79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns  
tgt77bz dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77ca dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77cb dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77cc sky @ 34 GHz @ 152 ft, gate 450 ns  
  
tgt77cd Man kneeling without RPG looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77ce Man standing with RPG at 45 degrees looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77cf Man kneeling with RPG at 45 degrees looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77cg Man prone without RPG looking rear on @ 5 degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
  
tgt77ch 79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns  
tgt77ci dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77cj dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77ck dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77cl sky @ 34 GHz @ 152 ft, gate 450 ns  
  
tgt77cm Man standing with RPG at 0 degrees looking rear on @ 15 degrees depression @ 34 GHz @ 152 ft, gate 450 ns

tgt77cn Man kneeling with RPG at 0 degrees looking rear on @  
15 degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77co Man prone with RPG at 0 degrees looking rear on @ 15  
degrees depression @ 34 GHz @ 152 ft, gate 450 ns

8/18/03 Sunny, warm, 80's

Operators: Bob Bender  
Don Testerman

tgt77cv 79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns  
tgt77cw dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77cx dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450  
ns  
tgt77cy dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77cz sky @ 34 GHz @ 152 ft, gate 450 ns

tgt77da Man standing with RPG at 22.5 degrees looking rear on  
@ 15 degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77db Man kneeling with RPG at 22.5 degrees looking rear on  
@ 15 degrees depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77dc Man kneeling without RPG looking rear on @ 15 degrees  
depression @ 34 GHz @ 152 ft, gate 450 ns  
tgt77dd Man with RPG kneeling rear on, 45 degrees RPG angle @  
2 degrees depression @ 34 GHz @ 152 ft, gate 450 ns (repeat of  
au--corrupted data file)

tgt77de 79.4 sqm trihedral @ 34 GHz @ 152 ft, gate 450 ns  
tgt77df dihedral at 0 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77dg dihedral at 22.5 degrees @ 34 GHz @ 152 ft, gate 450  
ns  
tgt77dh dihedral at 45 degrees @ 34 GHz @ 152 ft, gate 450 ns  
tgt77di sky @ 34 GHz @ 152 ft, gate 450 ns



---

## Appendix B. Polar Plots

---

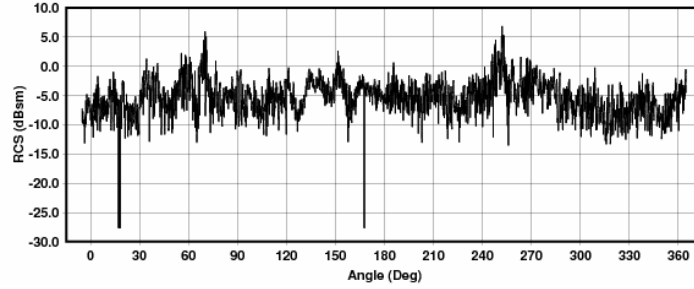
The RCS values for the plots shown in this appendix are computed with the following parameter values:

Center Frequency 34 GHz  
Range Bandwidth 1599.359 MHz  
Range Bin Size 4.00 m  
Angle Interval  $0.090^\circ$   
Window Size  $0.090^\circ$   
Window Step  $0.090^\circ$

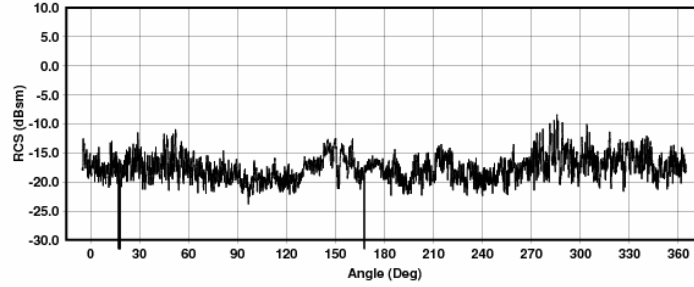
The range bin size defines the software gate centered around the target. Signals that are outside this “window” do not contribute to the RCS. The angle interval for the plots is 0.09 degree, although an angle increment of 0.015 degree was used to collect the data at Ka-band. Therefore, at Ka-Band, every sixth point is plotted. The plotted data are averaged with a moving average scheme where the window size divided by the angle interval defines the number of points in each averaging step, and the window step divided by the angle increment gives the number of points to slide to reach the start of the next window for averaging. Therefore, for these plots, there is no averaging.

A clutter subtraction algorithm is applied to each data set. The algorithm computes the coherent background signal level for a section of aspect angle around the angle for which the RCS is currently being calculated and subtracts that background value from the signal at the current angle.

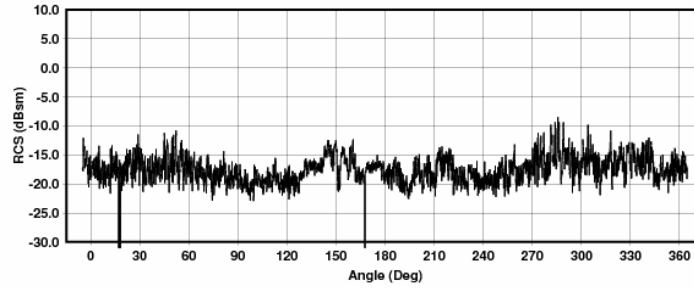
The linear polarized plots are shown next. A detailed listing of measurements is given in the logbook in appendix A.



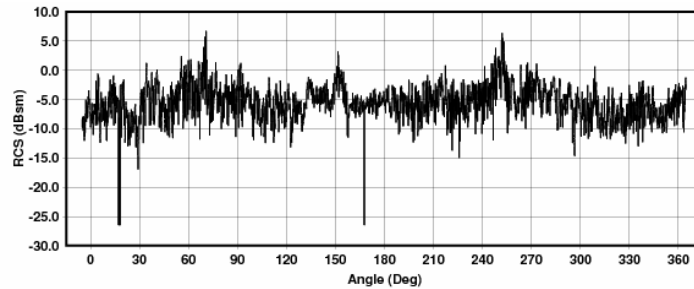
(a) Polarization = TVRV, Mean =  $-4.5$  dBsm, Median =  $-5.2$  dBsm, Standard Deviation =  $6.9$  dBsm



(b) Polarization = TVRH, Mean =  $-17.1$  dBsm, Median =  $-17.6$  dBsm, Standard Deviation =  $12.3$  dBsm

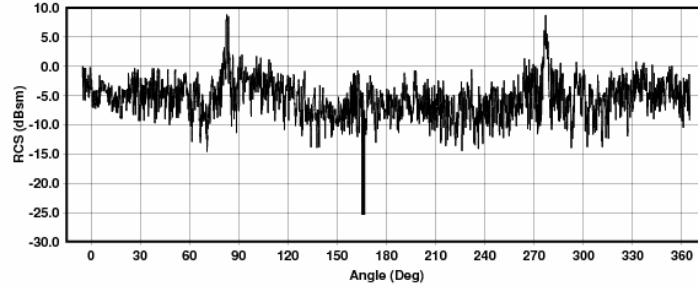


(c) Polarization = THRV, Mean =  $-17.0$  dBsm, Median =  $-17.4$  dBsm, Standard Deviation =  $12.3$  dBsm

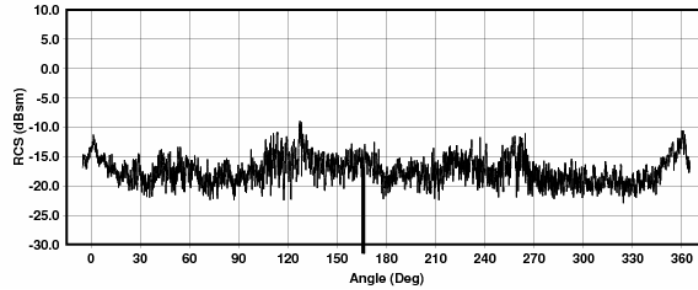


(d) Polarization = THRH, Mean =  $-4.6$  dBsm, Median =  $-5.4$  dBsm, Standard Deviation =  $7.0$  dBsm

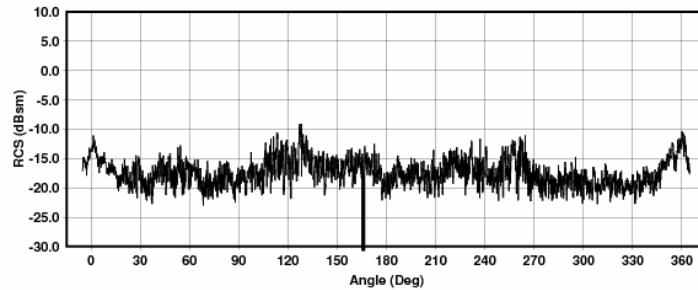
Figure B-1. RCS plots for trial TGT77AF, 2-degree depression, 0-degree RPG angle, man standing.



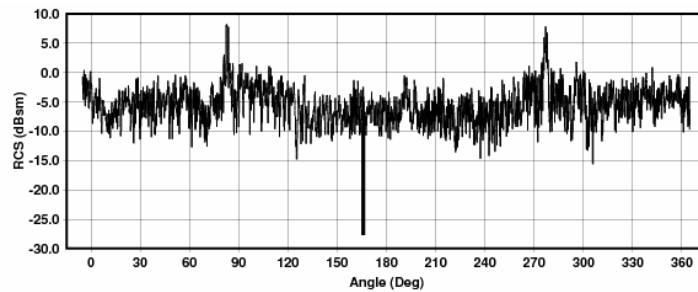
(a) Polarization = TVRV, Mean =  $-4.3$  dBsm, Median =  $-5.4$  dBsm, Standard Deviation =  $6.7$  dBsm



(b) Polarization = TVRH, Mean =  $-17.0$  dBsm, Median =  $-17.6$  dBsm, Standard Deviation =  $12.3$  dBsm

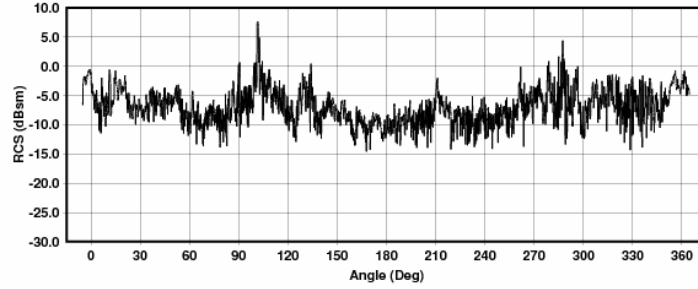


(c) Polarization = THRV, Mean =  $-17.0$  dBsm, Median =  $-17.6$  dBsm, Standard Deviation =  $12.3$  dBsm

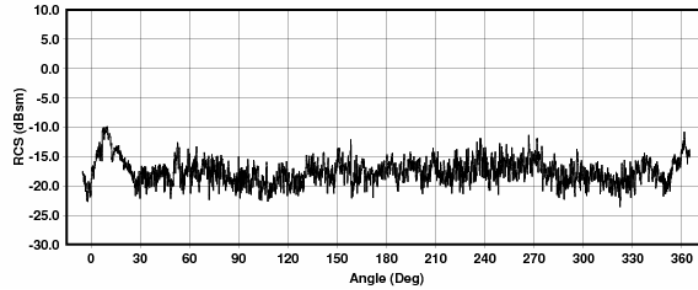


(d) Polarization = THRH, Mean =  $-4.5$  dBsm, Median =  $-5.6$  dBsm, Standard Deviation =  $6.9$  dBsm

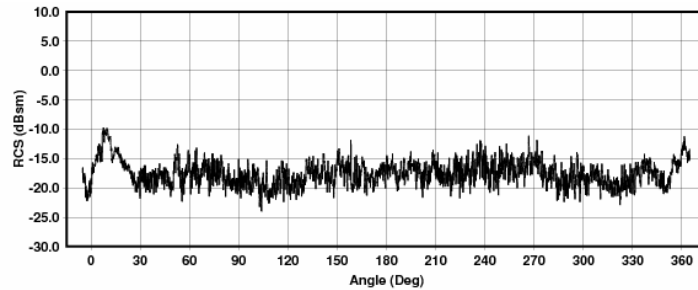
Figure B-2. RCS plots for trial TGT77AG, 2-degree depression, 0-degree RPG angle, man standing facing aft.



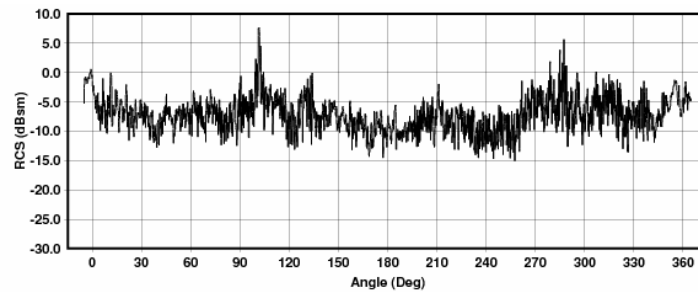
(a) Polarization = TVRV, Mean =  $-6.0$  dBsm, Median =  $-7.2$  dBsm, Standard Deviation =  $8.0$  dBsm



(b) Polarization = TVRH, Mean =  $-17.2$  dBsm, Median =  $-17.8$  dBsm, Standard Deviation =  $12.4$  dBsm

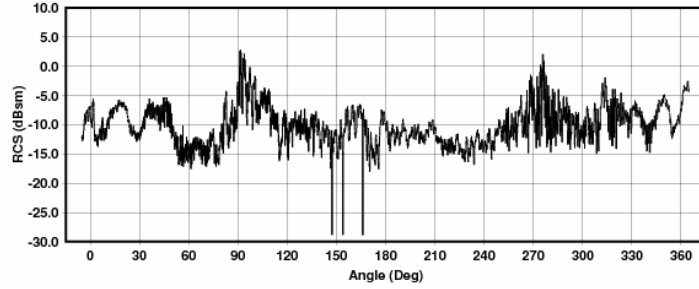


(c) Polarization = THRV, Mean =  $-17.2$  dBsm, Median =  $-17.6$  dBsm, Standard Deviation =  $12.4$  dBsm

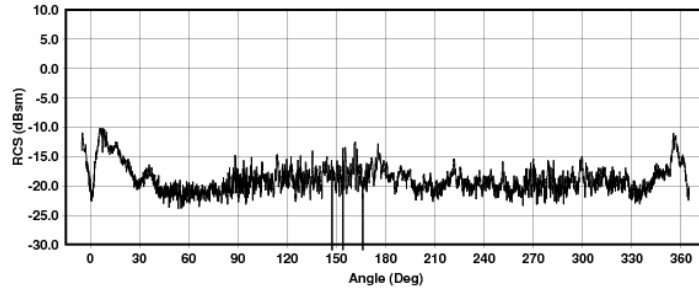


(d) Polarization = THRH, Mean =  $-6.1$  dBsm, Median =  $-7.2$  dBsm, Standard Deviation =  $8.0$  dBsm

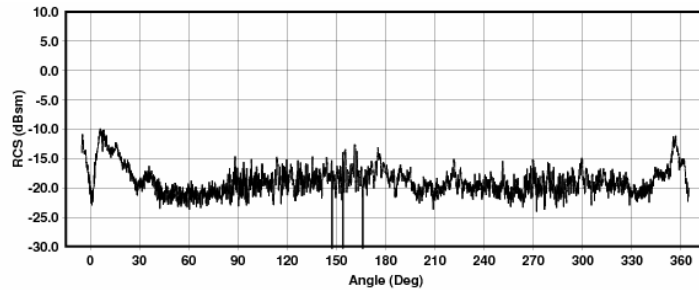
Figure B-3. RCS plots for trial TGT77AH, 2-degree depression, RPG angle 0-degree, man kneeling facing aft.



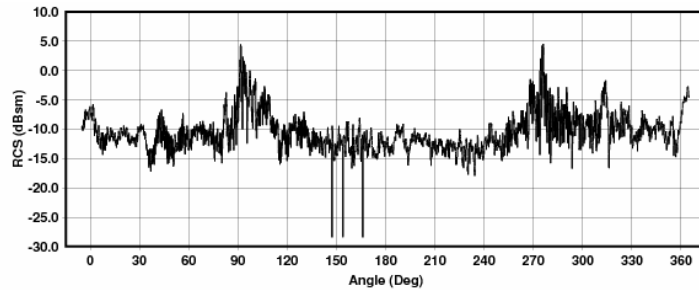
(a) Polarization = TVRV, Mean = -9.0 dBsm, Median = -10.4 dBsm, Standard Deviation = 9.6 dBsm



(b) Polarization = TVRH, Mean = -18.4 dBsm, Median = -19.2 dBsm, Standard Deviation = 12.6 dBsm

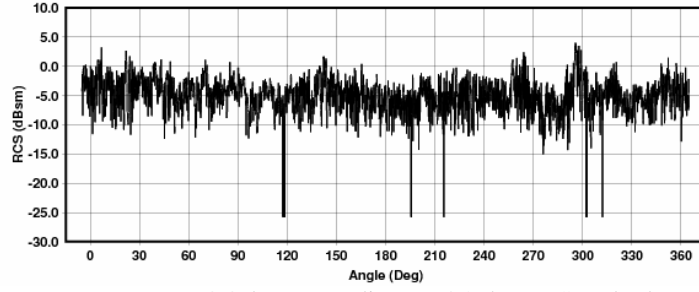


(c) Polarization = THRV, Mean = -18.3 dBsm, Median = -19.2 dBsm, Standard Deviation = 12.6 dBsm

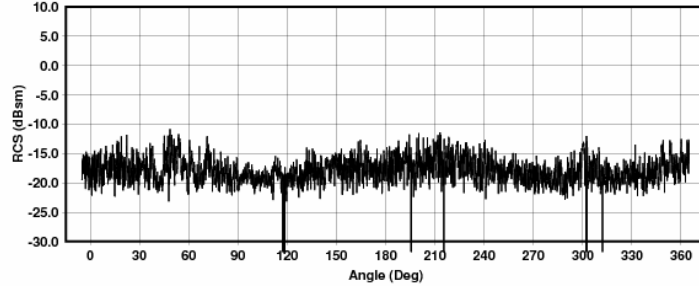


(d) Polarization = THRH, Mean = -9.2 dBsm, Median = -11.0 dBsm, Standard Deviation = 9.7 dBsm

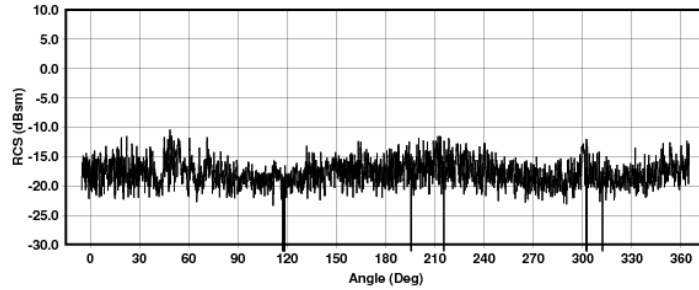
Figure B-4. RCS plots for trial TGT77AI, 2-degree depression, 0-degree RPG angle, man prone facing aft.



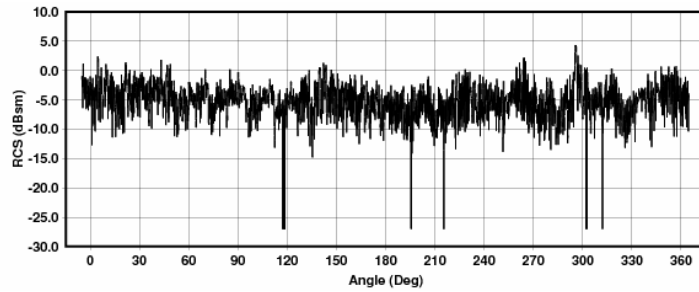
(a) Polarization = TVRV, Mean =  $-4.4$  dBsm, Median =  $-4.8$  dBsm, Standard Deviation =  $6.8$  dBsm



(b) Polarization = TVRH, Mean =  $-17.5$  dBsm, Median =  $-18.0$  dBsm, Standard Deviation =  $12.4$  dBsm

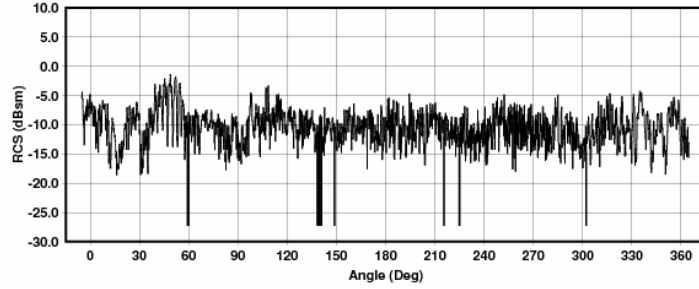


(c) Polarization = THRV, Mean =  $-17.4$  dBsm, Median =  $-17.8$  dBsm, Standard Deviation =  $12.4$  dBsm

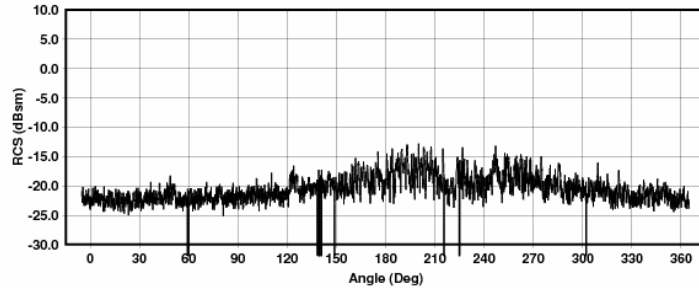


(d) Polarization = THRH, Mean =  $-4.6$  dBsm, Median =  $-5.0$  dBsm, Standard Deviation =  $6.9$  dBsm

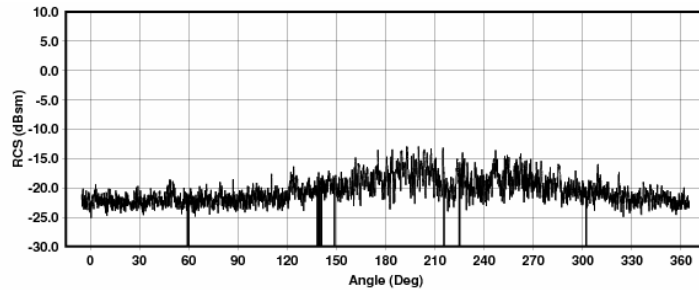
Figure B-5. RCS plots for trial TGT77AJ, 2-degree depression, 90-degree RPG angle, man standing facing aft.



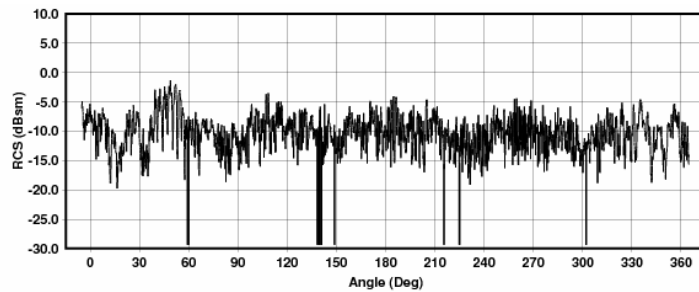
(a) Polarization = TVRV, Mean =  $-9.7$  dBsm, Median =  $-10.4$  dBsm, Standard Deviation =  $9.9$  dBsm



(b) Polarization = TVRH, Mean =  $-19.9$  dBsm, Median =  $-20.8$  dBsm, Standard Deviation =  $13.0$  dBsm

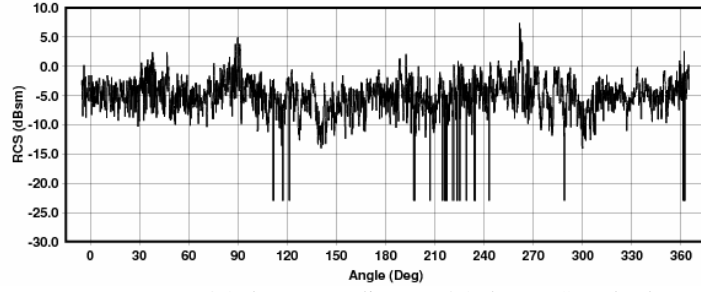


(c) Polarization = THRV, Mean =  $-19.9$  dBsm, Median =  $-20.8$  dBsm, Standard Deviation =  $13.0$  dBsm

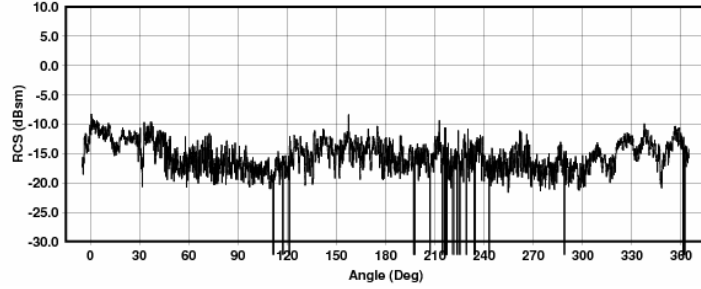


(d) Polarization = THRH, Mean =  $-9.6$  dBsm, Median =  $-10.2$  dBsm, Standard Deviation =  $9.9$  dBsm

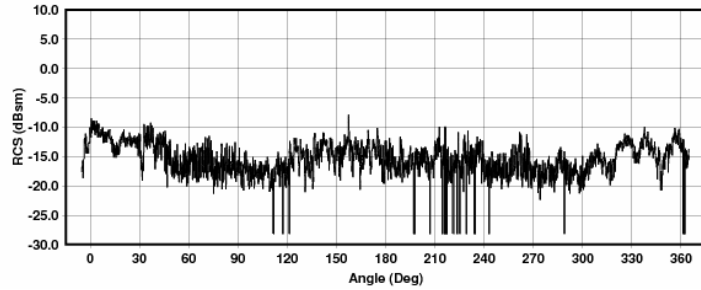
Figure B-6. RCS plots for trial TGT77AK, 2-degree depression, man without RPG kneeling facing aft.



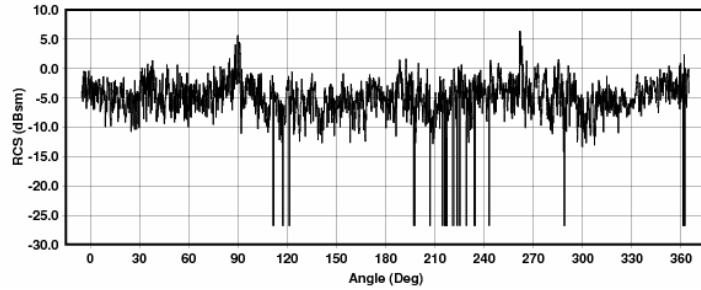
(a) Polarization = TVRV, Mean =  $-4.3$  dBsm, Median =  $-4.8$  dBsm, Standard Deviation =  $6.7$  dBsm



(b) Polarization = TVRH, Mean =  $-14.9$  dBsm, Median =  $-15.6$  dBsm, Standard Deviation =  $11.8$  dBsm



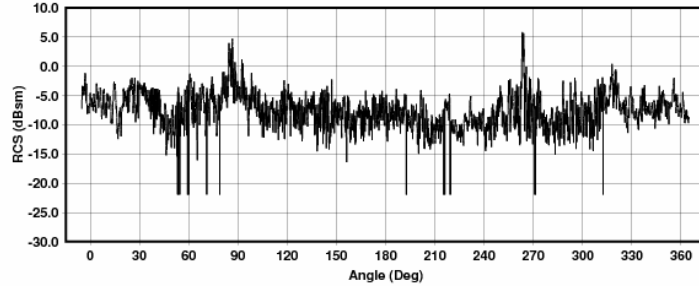
(c) Polarization = THRV, Mean =  $-14.8$  dBsm, Median =  $-15.4$  dBsm, Standard Deviation =  $11.7$  dBsm



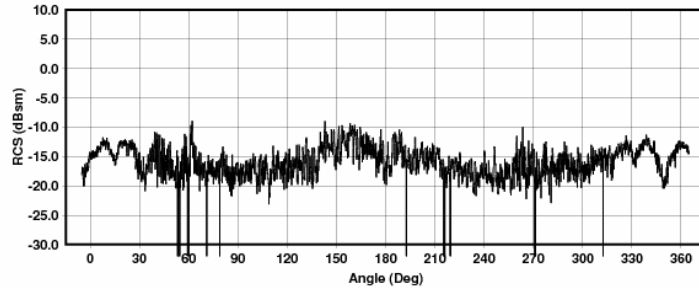
(d) Polarization = THRH, Mean =  $-4.2$  dBsm, Median =  $-4.6$  dBsm, Standard Deviation =  $6.6$  dBsm

Figure B-7. RCS plots for trial TGT77AQ, 2-degree depression, 22.5-degree RPG angle, man standing facing aft.

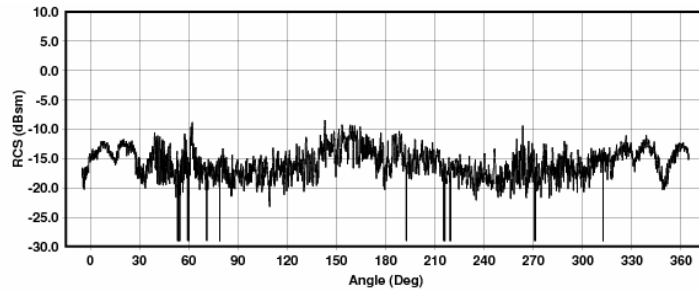




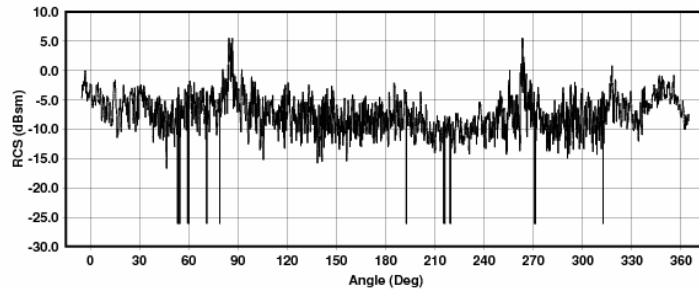
(a) Polarization = TVRV, Mean =  $-6.6$  dBsm, Median =  $-7.4$  dBsm, Standard Deviation =  $8.4$  dBsm



(b) Polarization = TVRH, Mean =  $-15.4$  dBsm, Median =  $-15.8$  dBsm, Standard Deviation =  $11.9$  dBsm

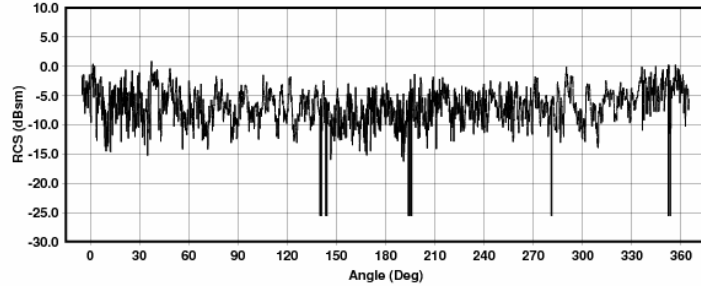


(c) Polarization = THRV, Mean =  $-15.3$  dBsm, Median =  $-15.8$  dBsm, Standard Deviation =  $11.9$  dBsm

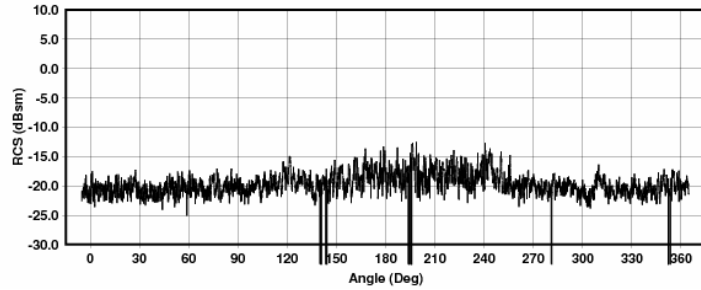


(d) Polarization = THRH, Mean =  $-6.3$  dBsm, Median =  $-7.2$  dBsm, Standard Deviation =  $8.2$  dBsm

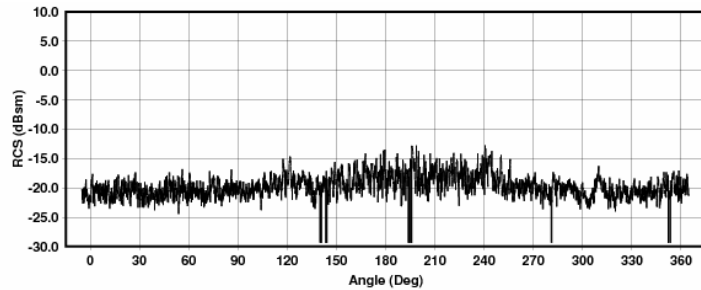
Figure B-8. RCS plots for trial TGT77AR, 2-degree depression, 22.5-degree RPG angle, man kneeling facing aft.



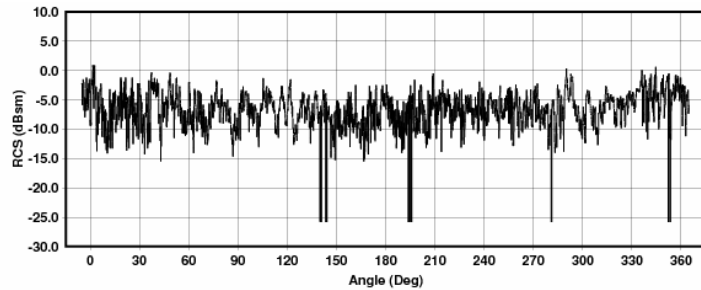
(a) Polarization = TVRV, Mean = -6.1 dBsm, Median = -6.6 dBsm, Standard Deviation = 8.0 dBsm



(b) Polarization = TVRH, Mean = -19.4 dBsm, Median = -19.8 dBsm, Standard Deviation = 12.9 dBsm

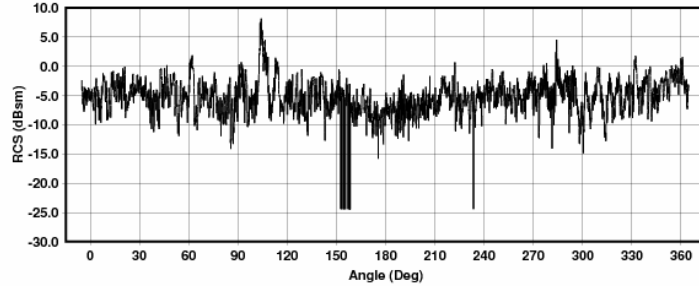


(c) Polarization = THRV, Mean = -19.4 dBsm, Median = -19.8 dBsm, Standard Deviation = 12.9 dBsm

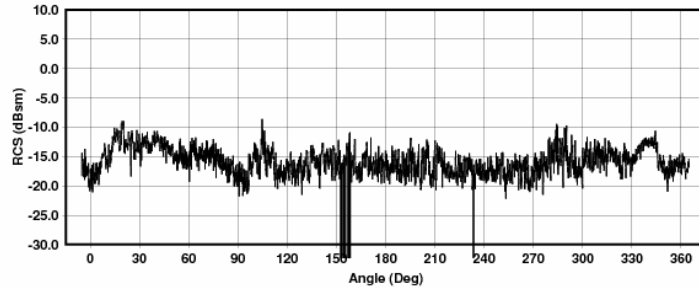


(d) Polarization = THRH, Mean = -6.0 dBsm, Median = -6.4 dBsm, Standard Deviation = 8.0 dBsm

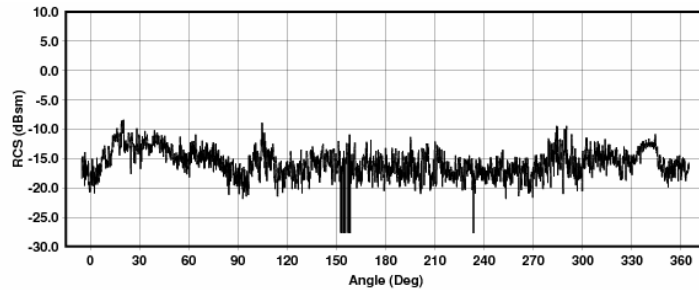
Figure B-9. RCS plots for trial TGT77AS, 2-degree depression, man without RPG standing facing aft.



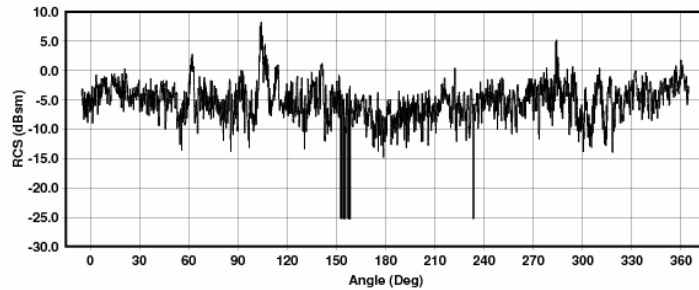
(a) Polarization = TVRV, Mean =  $-4.4$  dBsm, Median =  $-5.2$  dBsm, Standard Deviation =  $6.8$  dBsm



(b) Polarization = TVRH, Mean =  $-15.4$  dBsm, Median =  $-15.8$  dBsm, Standard Deviation =  $11.9$  dBsm

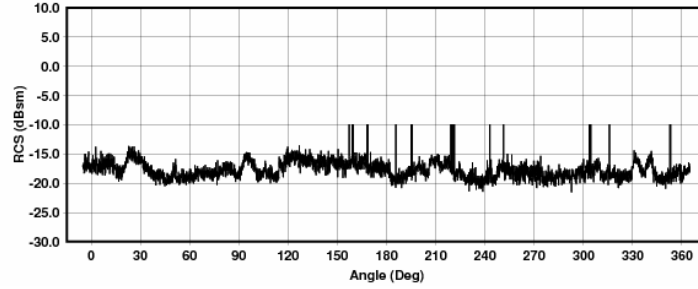


(c) Polarization = THRV, Mean =  $-15.3$  dBsm, Median =  $-15.8$  dBsm, Standard Deviation =  $11.8$  dBsm

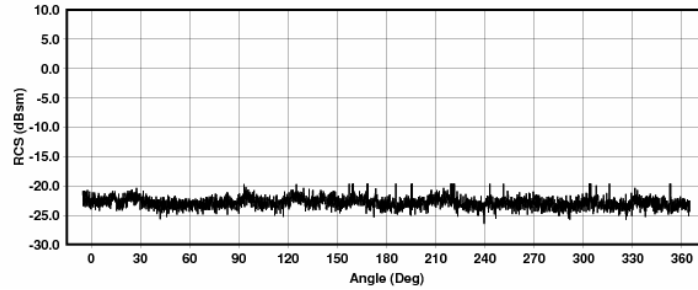


(d) Polarization = THRH, Mean =  $-4.4$  dBsm, Median =  $-5.0$  dBsm, Standard Deviation =  $6.8$  dBsm

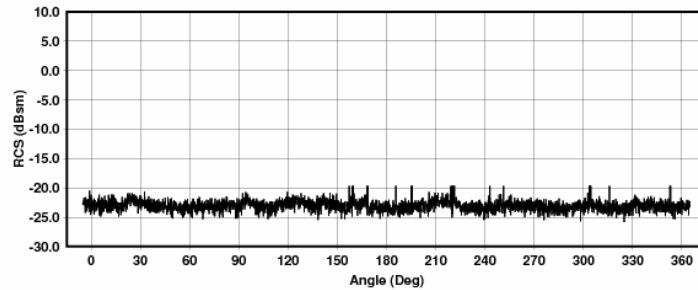
Figure B-10. RCS plots for trial TGT77AT, 2-degree depression, 45-degree RPG angle, man standing facing aft.



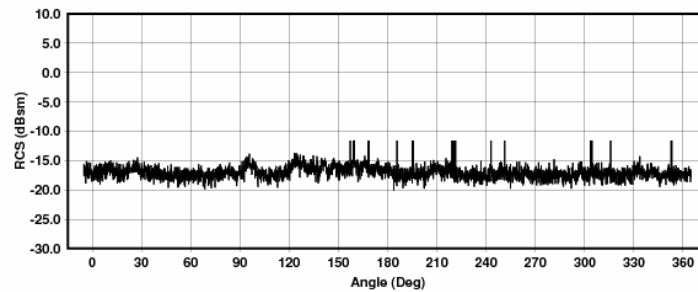
(a) Polarization = TVRV, Mean =  $-17.4$  dBsm, Median =  $-17.8$  dBsm, Standard Deviation =  $12.4$  dBsm



(b) Polarization = TVRH, Mean =  $-22.9$  dBsm, Median =  $-22.8$  dBsm, Standard Deviation =  $13.6$  dBsm

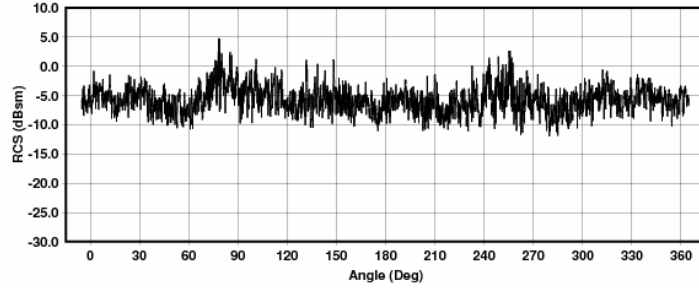


(c) Polarization = THRV, Mean =  $-23.1$  dBsm, Median =  $-23.0$  dBsm, Standard Deviation =  $13.6$  dBsm

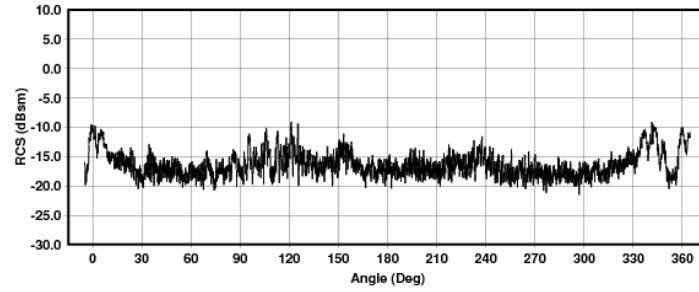


(d) Polarization = THRH, Mean =  $-17.0$  dBsm, Median =  $-17.0$  dBsm, Standard Deviation =  $12.3$  dBsm

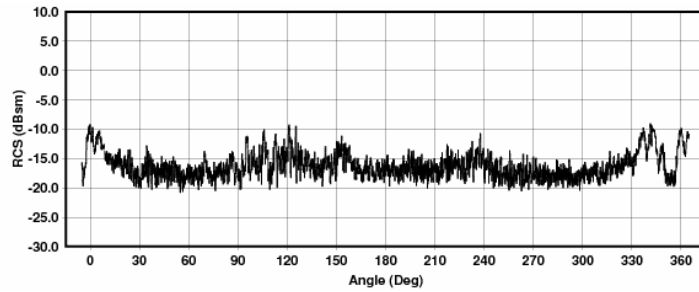
Figure B-11. RCS plots for trial TGT77AV, 2-degree depression, man without RPG, prone facing aft.



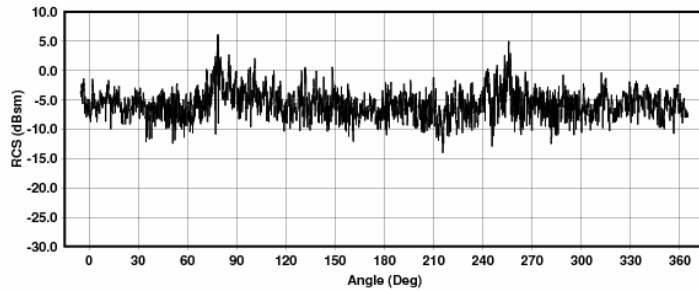
(a) Polarization = TVRV, Mean =  $-5.2$  dBsm, Median =  $-5.6$  dBsm, Standard Deviation =  $7.4$  dBsm



(b) Polarization = TVRH, Mean =  $-16.0$  dBsm, Median =  $-16.6$  dBsm, Standard Deviation =  $12.0$  dBsm

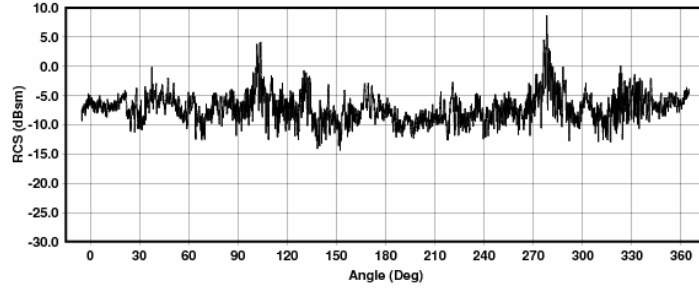


(c) Polarization = THRV, Mean =  $-15.8$  dBsm, Median =  $-16.6$  dBsm, Standard Deviation =  $12.0$  dBsm

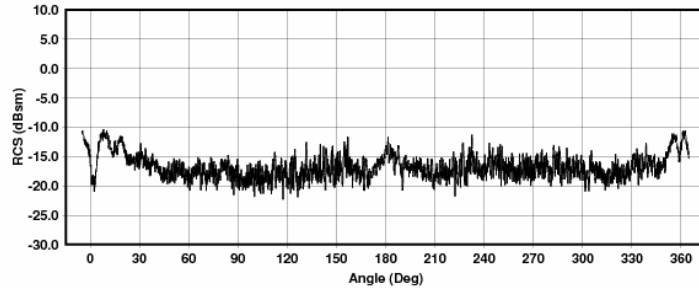


(d) Polarization = THRH, Mean =  $-5.1$  dBsm, Median =  $-5.8$  dBsm, Standard Deviation =  $7.3$  dBsm

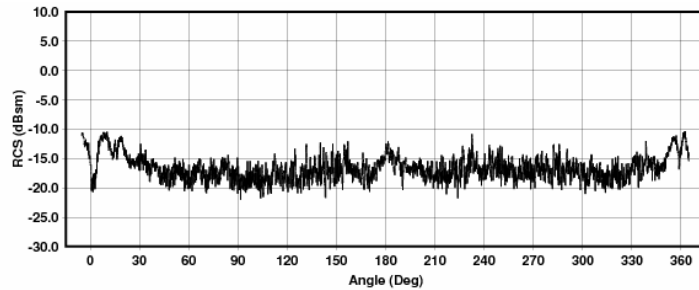
Figure B-12. RCS plots for trial TGT77BM, 5-degree depression, 0-degree RPG angle, man standing facing aft.



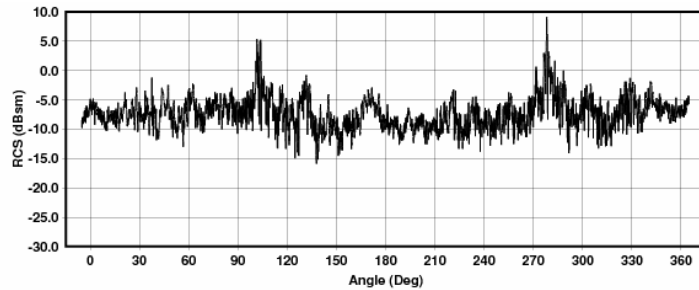
(a) Polarization = TVRV, Mean =  $-6.4$  dBsm, Median =  $-7.2$  dBsm, Standard Deviation =  $8.2$  dBsm



(b) Polarization = TVRH, Mean =  $-16.5$  dBsm, Median =  $-17.0$  dBsm, Standard Deviation =  $12.2$  dBsm

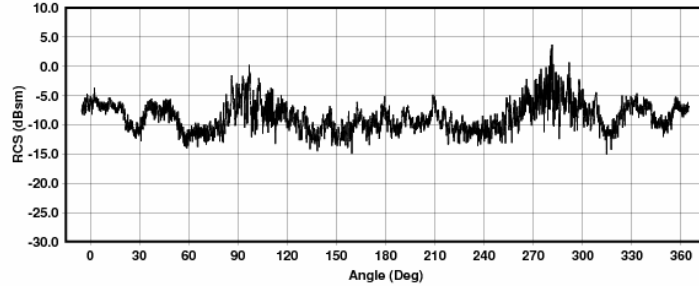


(c) Polarization = THRV, Mean =  $-16.4$  dBsm, Median =  $-16.8$  dBsm, Standard Deviation =  $12.2$  dBsm

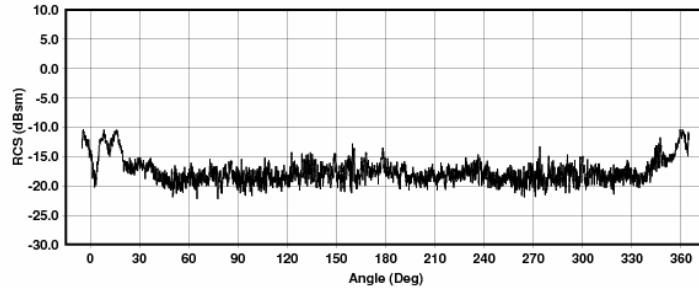


(d) Polarization = THRH, Mean =  $-6.4$  dBsm, Median =  $-7.4$  dBsm, Standard Deviation =  $8.2$  dBsm

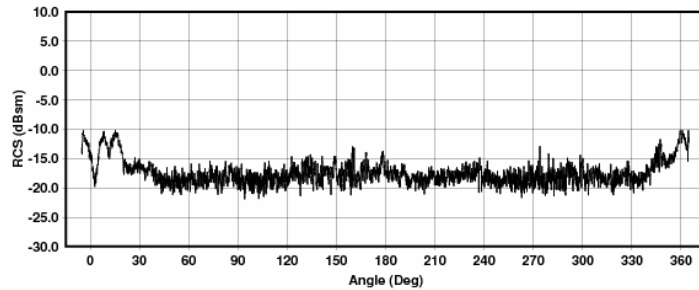
Figure B-13. RCS plots for trial TGT77BN, 5-degree depression, 0-degree RPG angle, man kneeling facing aft.



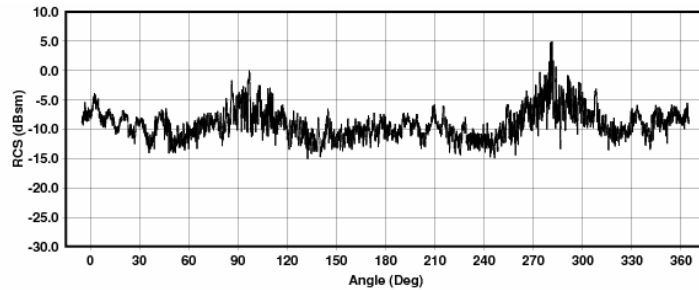
(a) Polarization = TVRV, Mean =  $-8.0$  dBsm, Median =  $-8.8$  dBsm, Standard Deviation =  $9.1$  dBsm



(b) Polarization = TVRH, Mean =  $-17.3$  dBsm, Median =  $-18.0$  dBsm, Standard Deviation =  $12.4$  dBsm

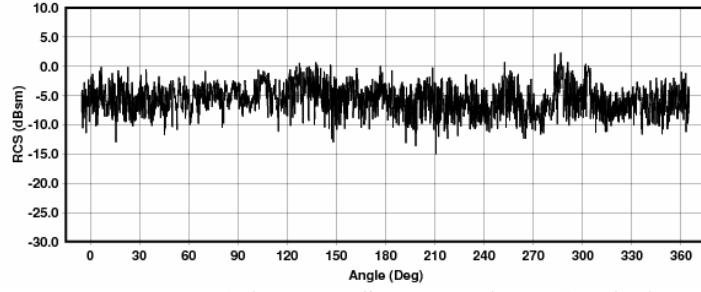


(c) Polarization = THRV, Mean =  $-17.2$  dBsm, Median =  $-17.8$  dBsm, Standard Deviation =  $12.4$  dBsm

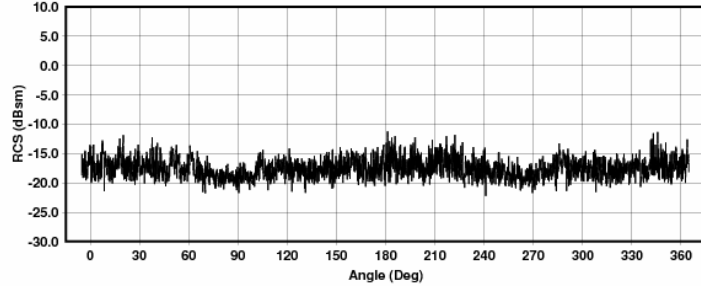


(d) Polarization = THRH, Mean =  $-8.3$  dBsm, Median =  $-9.2$  dBsm, Standard Deviation =  $9.2$  dBsm

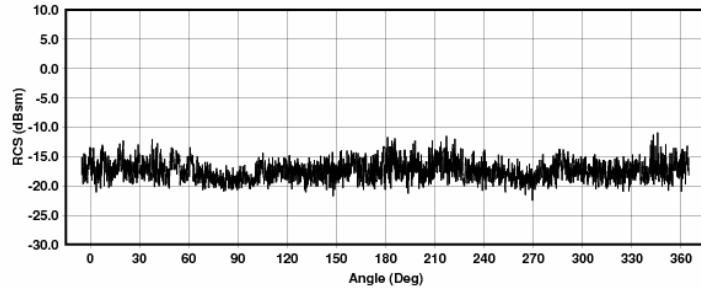
Figure B-14. RCS plots for trial TGT77BO, 5-degree depression, 0-degree RPG angle, man prone facing aft.



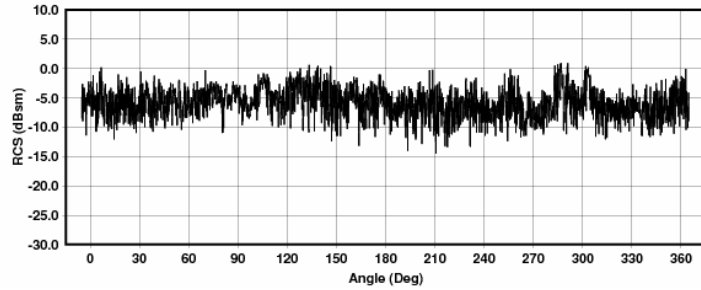
(a) Polarization = TVRV, Mean =  $-5.2$  dBsm, Median =  $-5.6$  dBsm, Standard Deviation =  $7.4$  dBsm



(b) Polarization = TVRH, Mean =  $-17.3$  dBsm, Median =  $-17.6$  dBsm, Standard Deviation =  $12.4$  dBsm



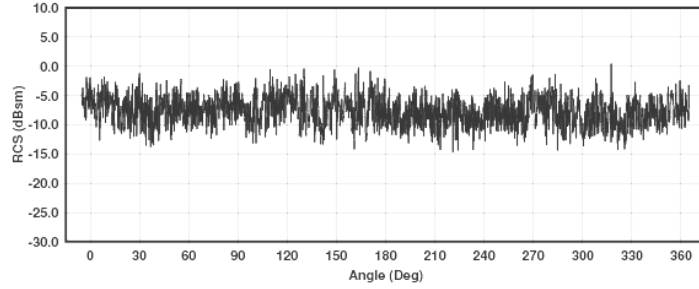
(c) Polarization = THRV, Mean =  $-17.2$  dBsm, Median =  $-17.4$  dBsm, Standard Deviation =  $12.4$  dBsm



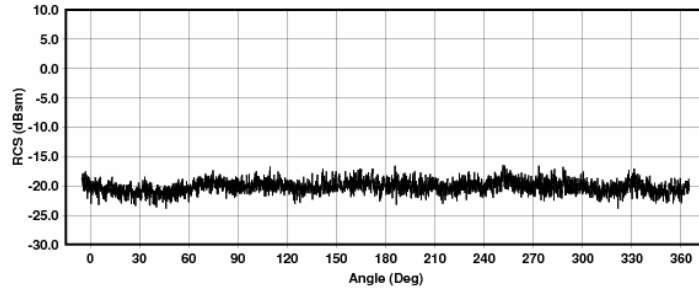
(d) Polarization = THRH, Mean =  $-5.4$  dBsm, Median =  $-5.8$  dBsm, Standard Deviation =  $7.6$  dBsm

Figure B-15. RCS plots for trial TGT77BP, 5-degree depression, 90-degree RPG angle, man standing facing aft.

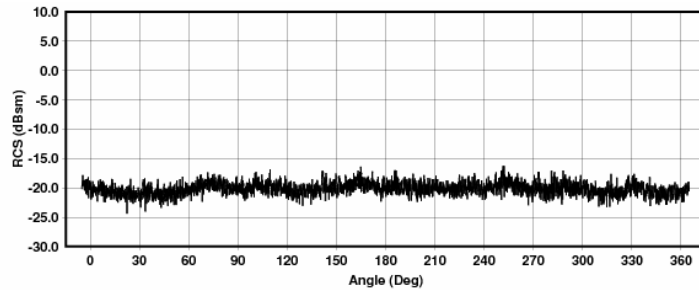




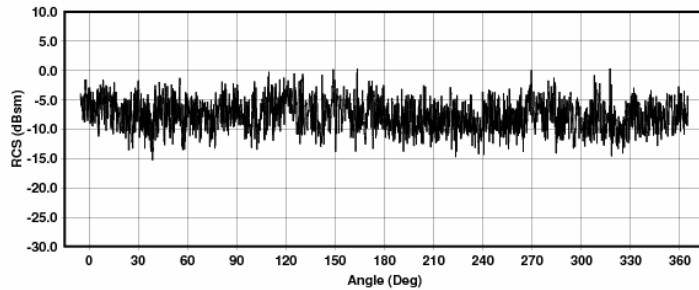
(a) Polarization = TVRV, Mean =  $-7.1$  dBsm, Median =  $-7.6$  dBsm, Standard Deviation =  $8.6$  dBsm



(b) Polarization = TVRH, Mean =  $-20.1$  dBsm, Median =  $-20.2$  dBsm, Standard Deviation =  $13.0$  dBsm

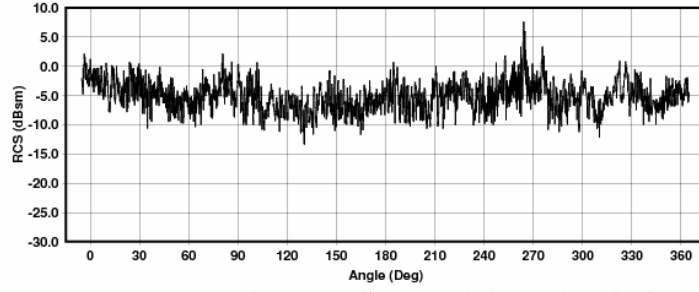


(c) Polarization = THRV, Mean =  $-20.1$  dBsm, Median =  $-20.2$  dBsm, Standard Deviation =  $13.0$  dBsm

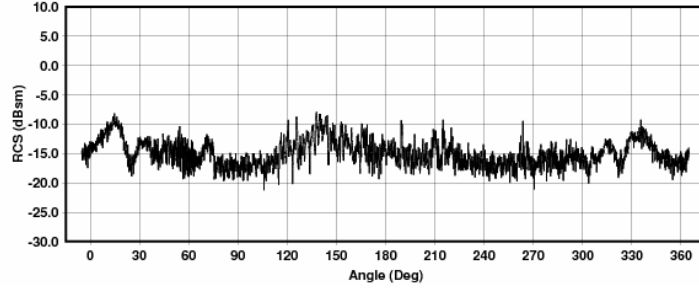


(d) Polarization = THRH, Mean =  $-7.0$  dBsm, Median =  $-7.4$  dBsm, Standard Deviation =  $8.6$  dBsm

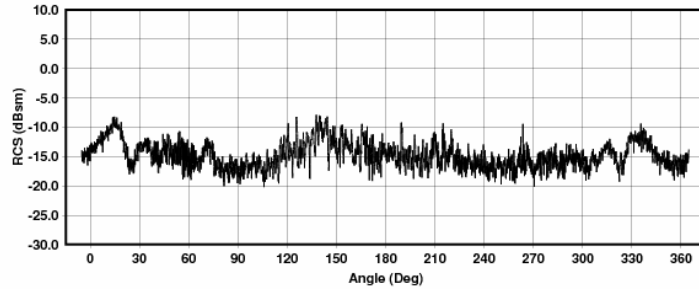
Figure B-16. RCS plots for trial TGT77BQ, 5-degree depression, man standing without RPG facing aft.



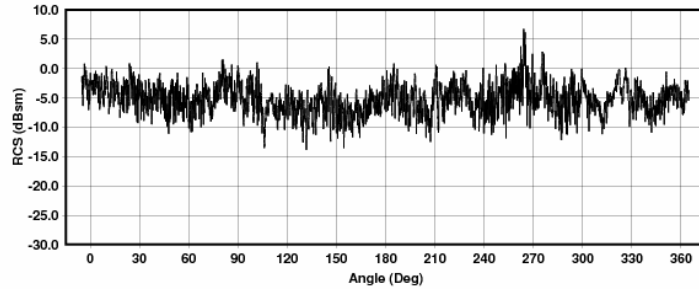
(a) Polarization = TVRV, Mean =  $-4.4$  dBsm, Median =  $-5.0$  dBsm, Standard Deviation =  $6.8$  dBsm



(b) Polarization = TVRH, Mean =  $-14.4$  dBsm, Median =  $-15.0$  dBsm, Standard Deviation =  $11.6$  dBsm

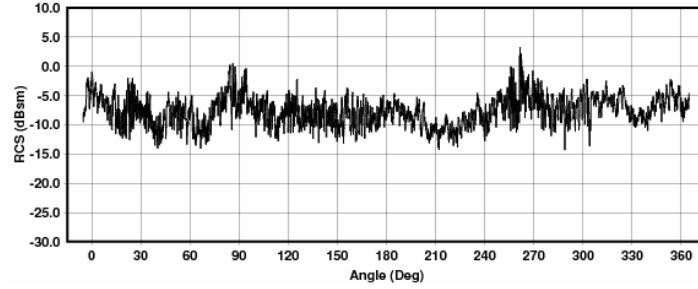


(c) Polarization = THRV, Mean =  $-14.2$  dBsm, Median =  $-14.8$  dBsm, Standard Deviation =  $11.5$  dBsm

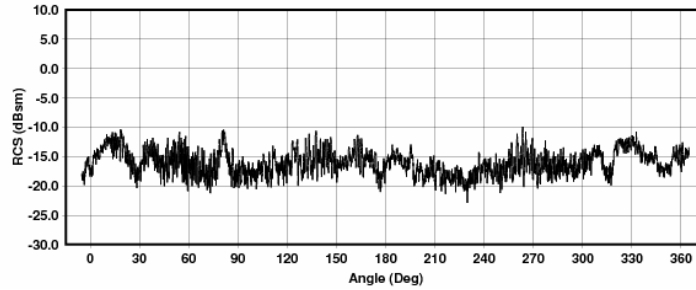


(d) Polarization = THRH, Mean =  $-4.5$  dBsm, Median =  $-5.2$  dBsm, Standard Deviation =  $6.8$  dBsm

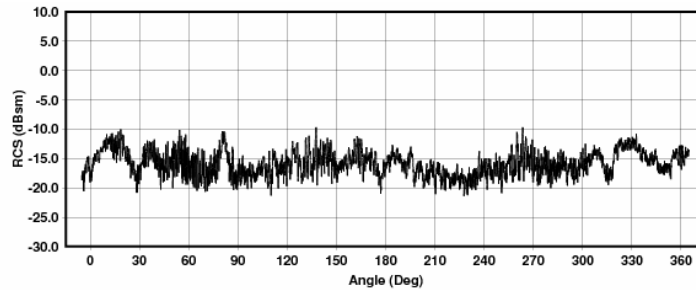
Figure B-17. RCS plots for trial TGT77BW, 5-degree depression, 22.5-degree RPG angle, man standing facing aft.



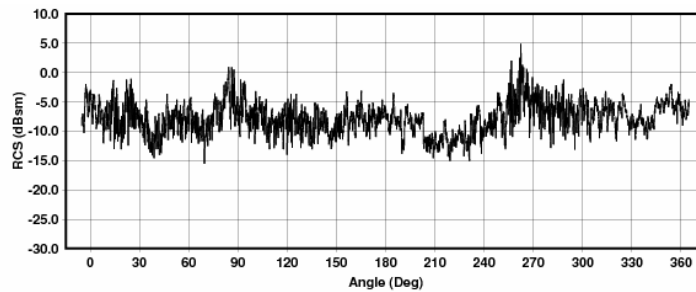
(a) Polarization = TVRV, Mean =  $-7.0$  dBsm, Median =  $-7.6$  dBsm, Standard Deviation =  $8.6$  dBsm



(b) Polarization = TVRH, Mean =  $-15.7$  dBsm, Median =  $-16.2$  dBsm, Standard Deviation =  $12.0$  dBsm

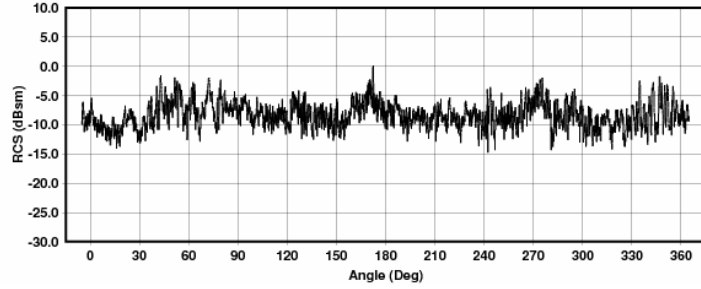


(c) Polarization = THRV, Mean =  $-15.5$  dBsm, Median =  $-16.0$  dBsm, Standard Deviation =  $11.9$  dBsm

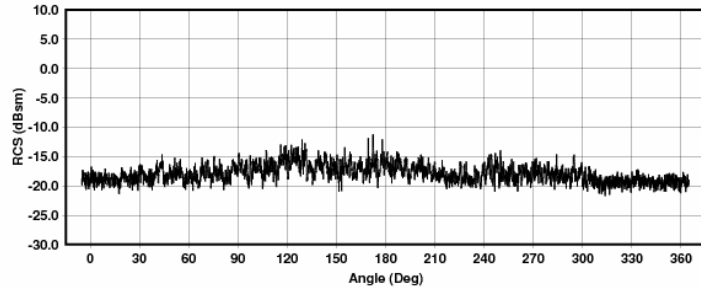


(d) Polarization = THRH, Mean =  $-7.0$  dBsm, Median =  $-7.8$  dBsm, Standard Deviation =  $8.6$  dBsm

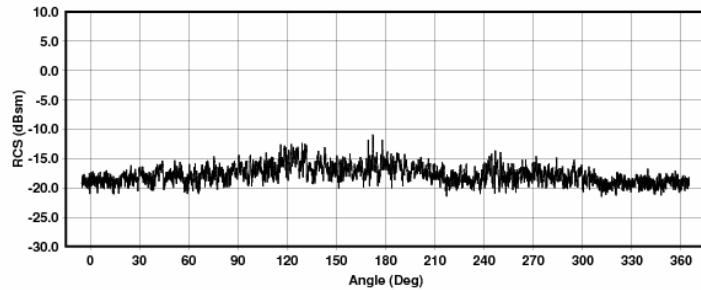
Figure B-18. RCS plots for trial TGT77BX, 5-degree depression, 22.5-degree RPG angle, man kneeling facing aft.



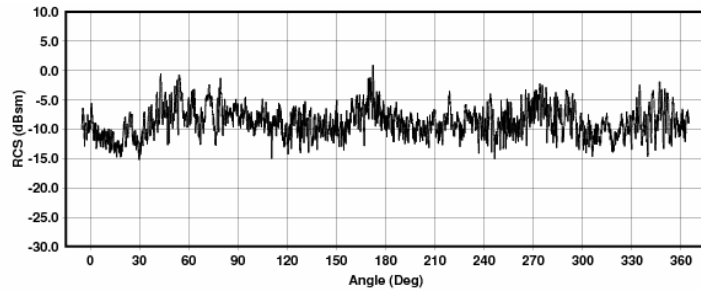
(a) Polarization = TVRV, Mean =  $-7.8$  dBsm, Median =  $-8.4$  dBsm, Standard Deviation =  $9.0$  dBsm



(b) Polarization = TVRH, Mean =  $-17.7$  dBsm, Median =  $-18.0$  dBsm, Standard Deviation =  $12.5$  dBsm

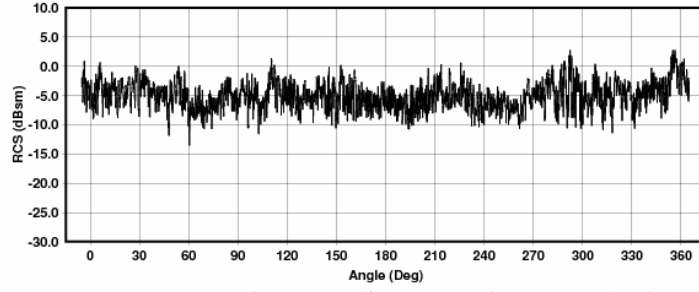


(c) Polarization = THRV, Mean =  $-17.6$  dBsm, Median =  $-17.8$  dBsm, Standard Deviation =  $12.5$  dBsm

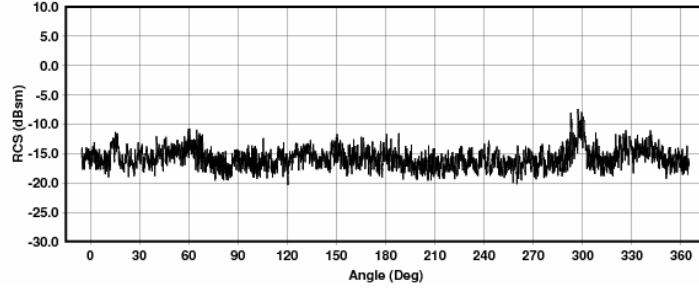


(d) Polarization = THRH, Mean =  $-8.1$  dBsm, Median =  $-8.8$  dBsm, Standard Deviation =  $9.1$  dBsm

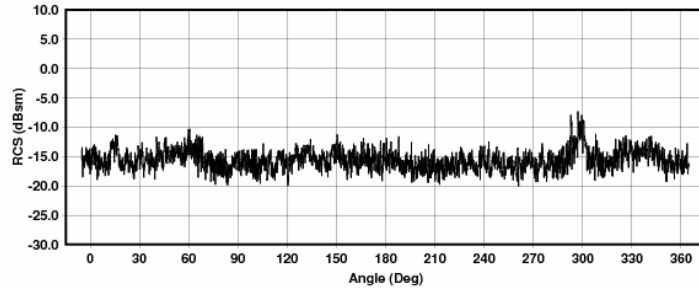
Figure B-19. RCS plots for trial TGT77CD, 5-degree depression, man without RPG kneeling facing aft.



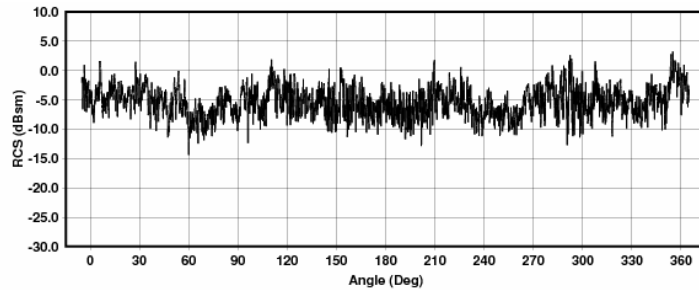
(a) Polarization = TVRV, Mean =  $-4.7$  dBsm, Median =  $-5.2$  dBsm, Standard Deviation =  $7.0$  dBsm



(b) Polarization = TVRH, Mean =  $-15.5$  dBsm, Median =  $-15.8$  dBsm, Standard Deviation =  $11.9$  dBsm

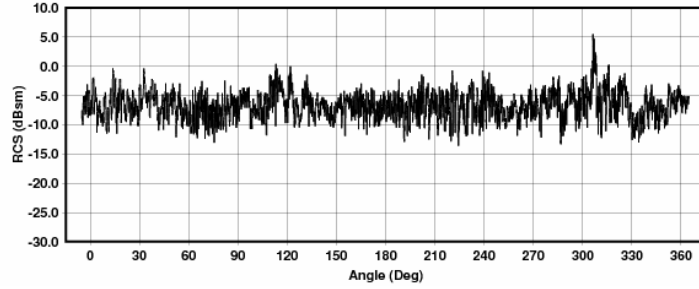


(c) Polarization = THRV, Mean =  $-15.3$  dBsm, Median =  $-15.6$  dBsm, Standard Deviation =  $11.9$  dBsm

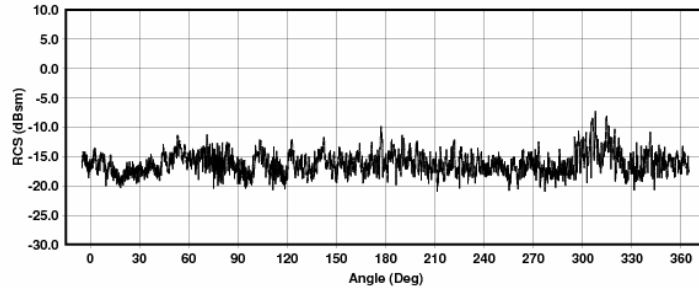


(d) Polarization = THRH, Mean =  $-4.9$  dBsm, Median =  $-5.4$  dBsm, Standard Deviation =  $7.2$  dBsm

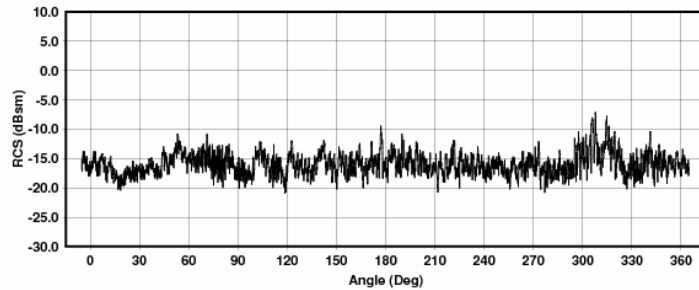
Figure B-20. RCS plots for trial TGT77CE, 5-degree depression, 45-degree RPG angle, man standing facing aft.



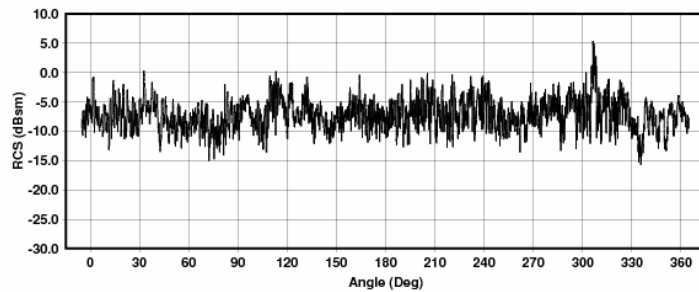
(a) Polarization = TVRV, Mean =  $-6.1$  dBsm, Median =  $-6.6$  dBsm, Standard Deviation =  $8.0$  dBsm



(b) Polarization = TVRH, Mean =  $-15.8$  dBsm, Median =  $-16.2$  dBsm, Standard Deviation =  $12.0$  dBsm

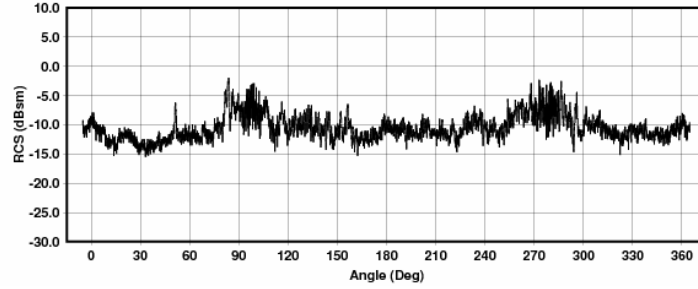


(c) Polarization = THRV, Mean =  $-15.6$  dBsm, Median =  $-16.0$  dBsm, Standard Deviation =  $11.9$  dBsm

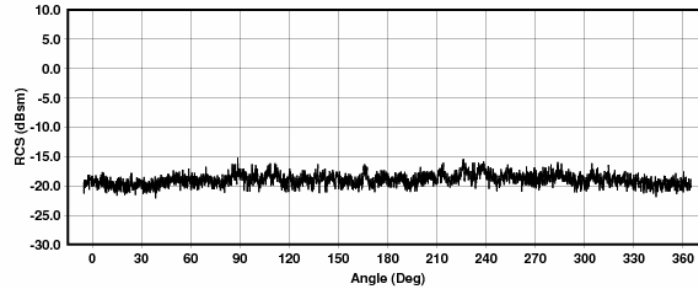


(d) Polarization = THRH, Mean =  $-6.4$  dBsm, Median =  $-7.2$  dBsm, Standard Deviation =  $8.2$  dBsm

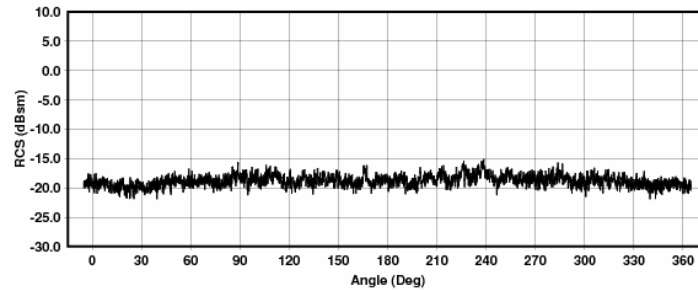
Figure B-21. RCS plots for trial TGT77CF, 5-degree depression, 45-degree RPG angle, man kneeling facing aft.



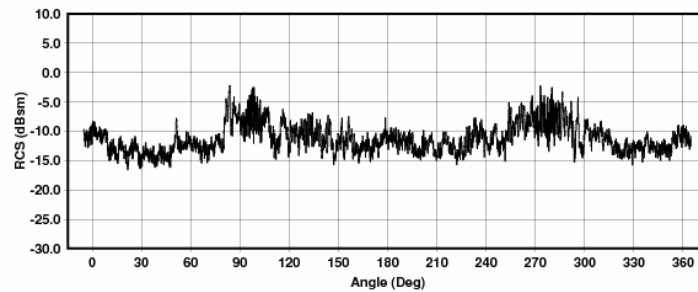
(a) Polarization = TVRV, Mean =  $-10.0$  dBsm, Median =  $-10.8$  dBsm, Standard Deviation =  $10.0$  dBsm



(b) Polarization = TVRH, Mean =  $-19.0$  dBsm, Median =  $-19.0$  dBsm, Standard Deviation =  $12.8$  dBsm

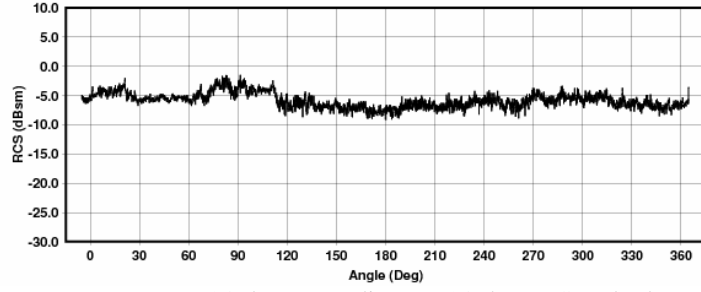


(c) Polarization = THRV, Mean =  $-18.8$  dBsm, Median =  $-18.8$  dBsm, Standard Deviation =  $12.7$  dBsm

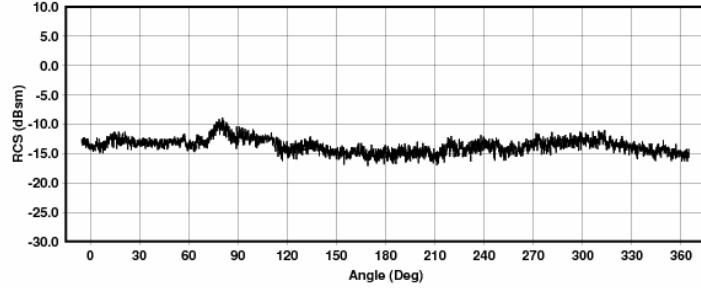


(d) Polarization = THRH, Mean =  $-10.6$  dBsm, Median =  $-11.6$  dBsm, Standard Deviation =  $10.3$  dBsm

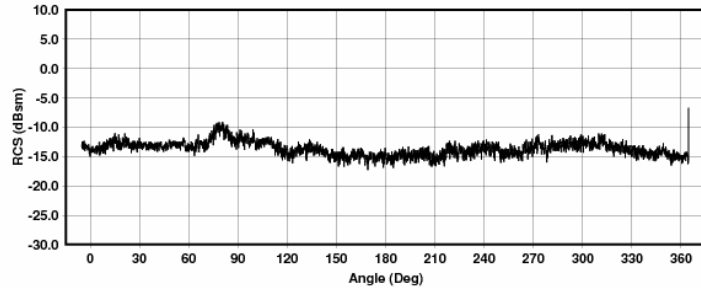
Figure B-22. RCS plots for trial TGT77CG, 5-degree depression, man without RPG prone facing aft.



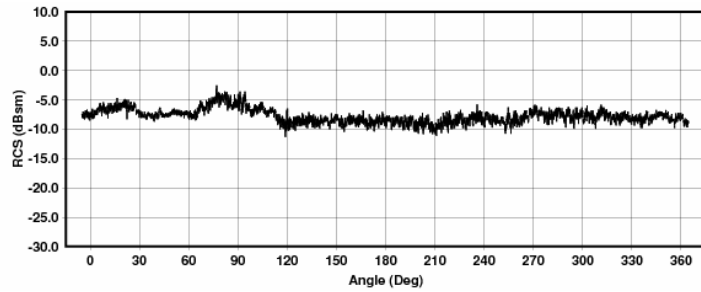
(a) Polarization = TVRV, Mean =  $-5.8$  dBsm, Median =  $-5.8$  dBsm, Standard Deviation =  $7.8$  dBsm



(b) Polarization = TVRH, Mean =  $-13.6$  dBsm, Median =  $-13.6$  dBsm, Standard Deviation =  $11.4$  dBsm



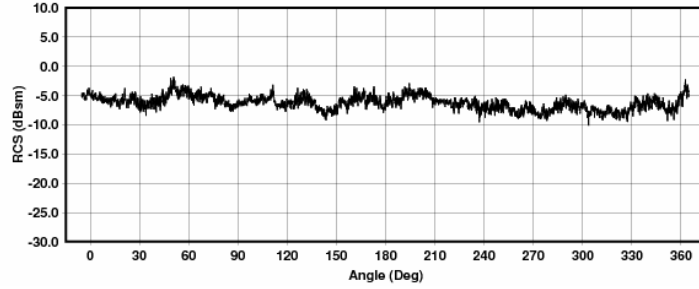
(c) Polarization = THRV, Mean =  $-13.6$  dBsm, Median =  $-13.6$  dBsm, Standard Deviation =  $11.3$  dBsm



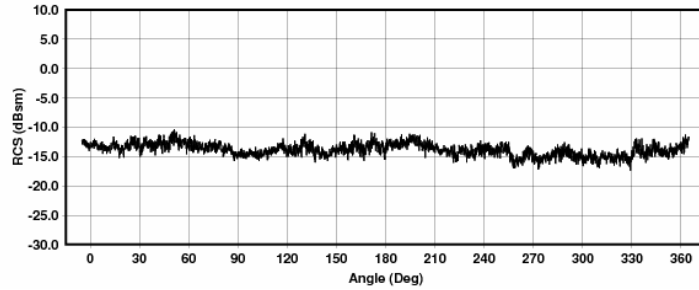
(d) Polarization = THRH, Mean =  $-7.7$  dBsm, Median =  $-7.8$  dBsm, Standard Deviation =  $9.0$  dBsm

Figure B-23. RCS plots for trial TGT77CM, 15-degree depression, 0-degree RPG angle, man standing facing aft.

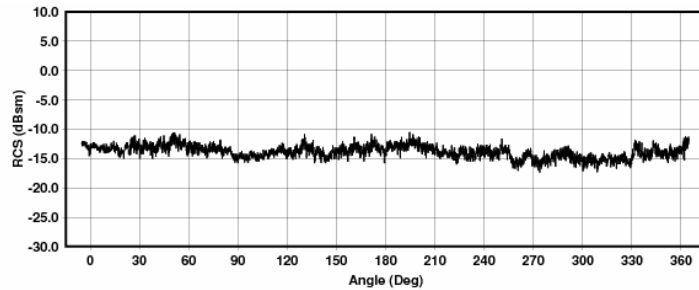




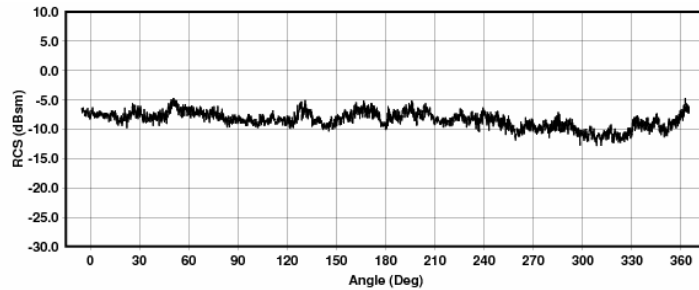
(a) Polarization = TVRV, Mean = -6.2 dBsm, Median = -6.2 dBsm, Standard Deviation = 8.1 dBsm



(b) Polarization = TVRH, Mean = -13.8 dBsm, Median = -13.8 dBsm, Standard Deviation = 11.4 dBsm

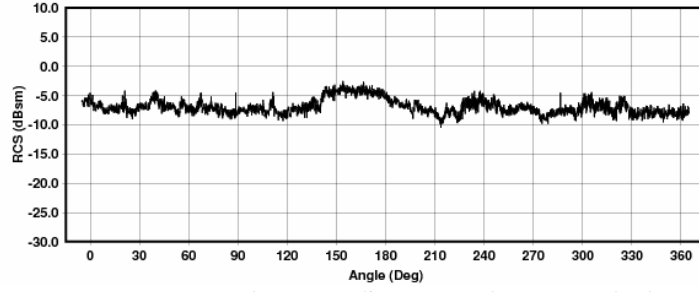


(c) Polarization = THRV, Mean = -13.8 dBsm, Median = -13.8 dBsm, Standard Deviation = 11.4 dBsm

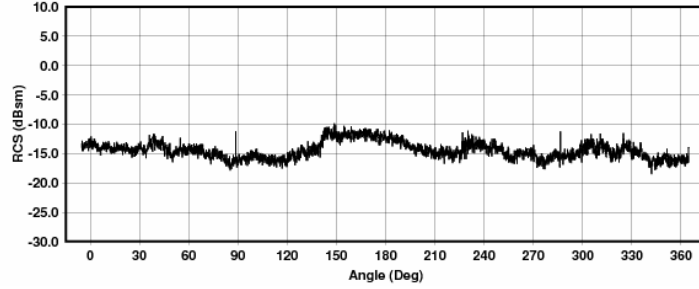


(d) Polarization = THRH, Mean = -8.4 dBsm, Median = -8.4 dBsm, Standard Deviation = 9.3 dBsm

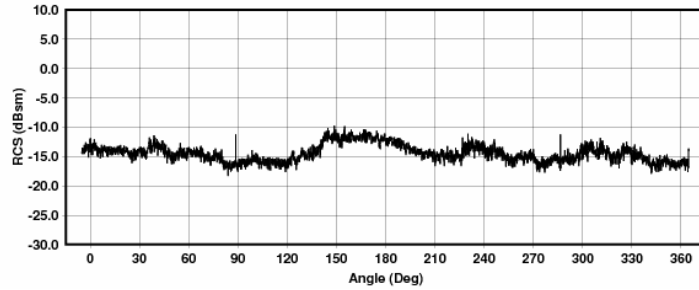
Figure B-24. RCS plots for trial TGT77CN, 15-degree depression, 0-degree RPG angle, man kneeling facing aft.



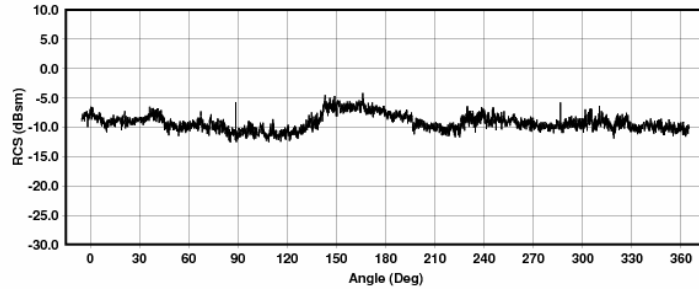
(a) Polarization = TVRV, Mean =  $-6.8$  dBsm, Median =  $-7.2$  dBsm, Standard Deviation =  $8.5$  dBsm



(b) Polarization = TVRH, Mean =  $-14.3$  dBsm, Median =  $-14.4$  dBsm, Standard Deviation =  $11.6$  dBsm

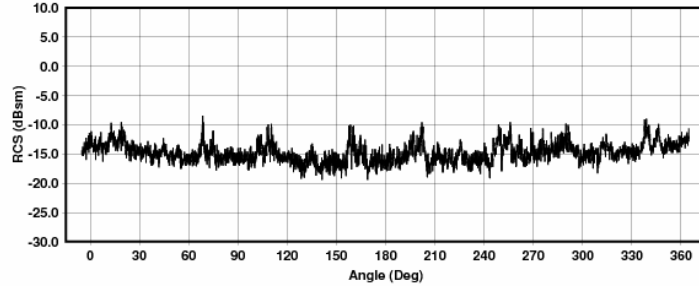


(c) Polarization = THRV, Mean =  $-14.3$  dBsm, Median =  $-14.4$  dBsm, Standard Deviation =  $11.6$  dBsm

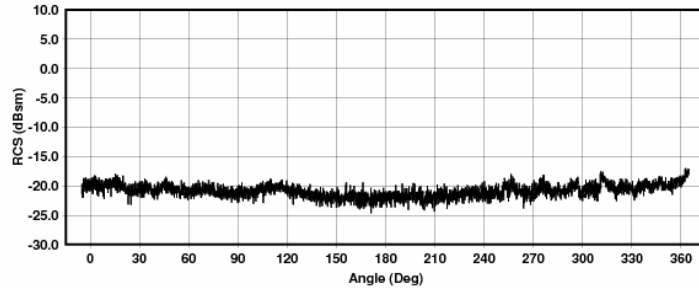


(d) Polarization = THRH, Mean =  $-9.1$  dBsm, Median =  $-9.4$  dBsm, Standard Deviation =  $9.6$  dBsm

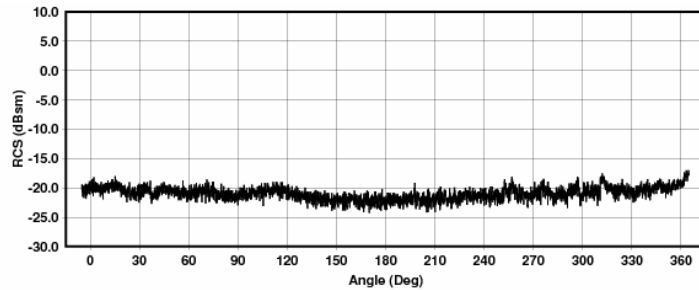
Figure B-25. RCS plots for trial TGT77CO, 15-degree depression, 0-degree RPG angle, man prone facing aft.



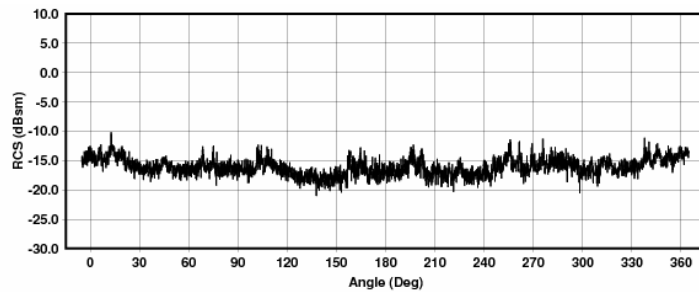
(a) Polarization = TVRV, Mean =  $-14.7$  dBsm, Median =  $-15.0$  dBsm, Standard Deviation =  $11.7$  dBsm



(b) Polarization = TVRH, Mean =  $-20.9$  dBsm, Median =  $-20.8$  dBsm, Standard Deviation =  $13.2$  dBsm

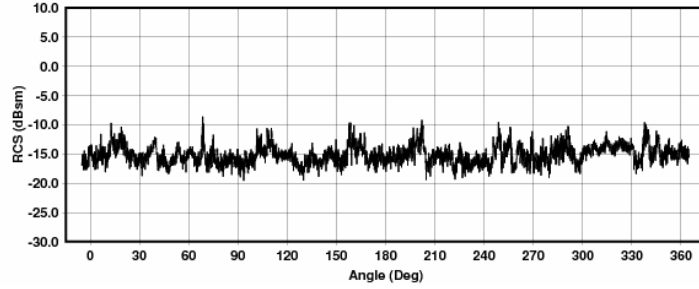


(c) Polarization = THRV, Mean =  $-21.0$  dBsm, Median =  $-21.0$  dBsm, Standard Deviation =  $13.2$  dBsm

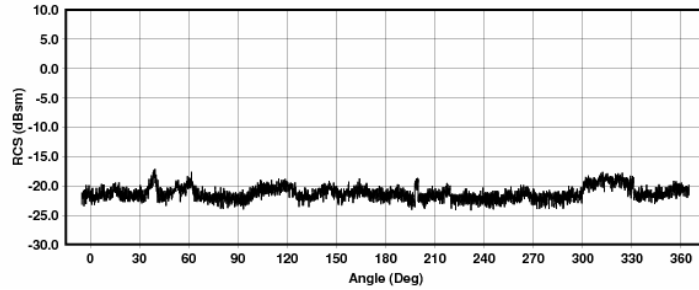


(d) Polarization = THRH, Mean =  $-16.0$  dBsm, Median =  $-16.2$  dBsm, Standard Deviation =  $12.1$  dBsm

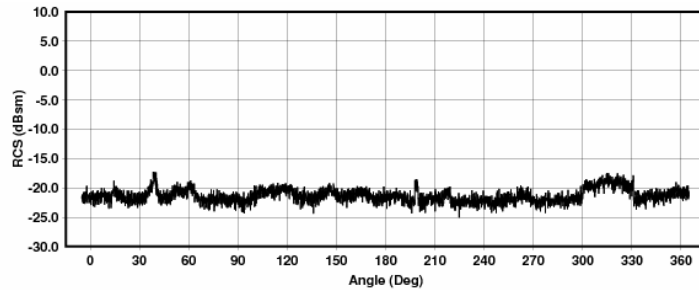
Figure B-26. RCS plots for trial TGT77DA, 15-degree depression, 22.5-degree RPG angle, man standing facing aft.



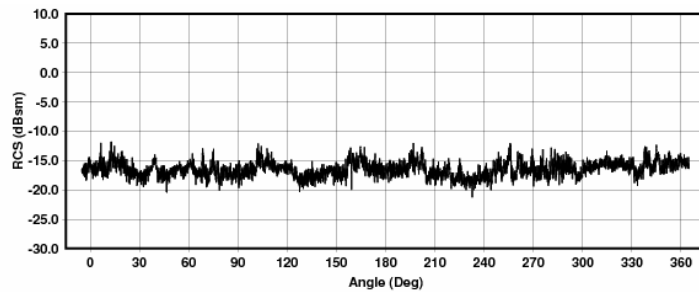
(a) Polarization = TVRV, Mean =  $-15.0$  dBsm, Median =  $-15.2$  dBsm, Standard Deviation =  $11.8$  dBsm



(b) Polarization = TVRH, Mean =  $-21.3$  dBsm, Median =  $-21.4$  dBsm, Standard Deviation =  $13.3$  dBsm

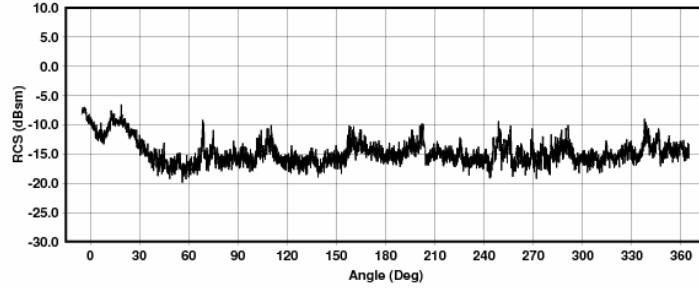


(c) Polarization = THRV, Mean =  $-21.3$  dBsm, Median =  $-21.4$  dBsm, Standard Deviation =  $13.3$  dBsm

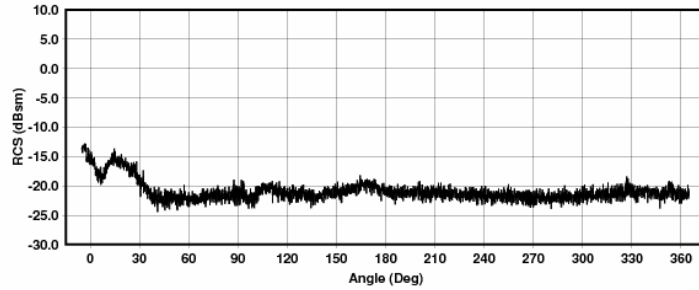


(d) Polarization = THRH, Mean =  $-16.4$  dBsm, Median =  $-16.6$  dBsm, Standard Deviation =  $12.2$  dBsm

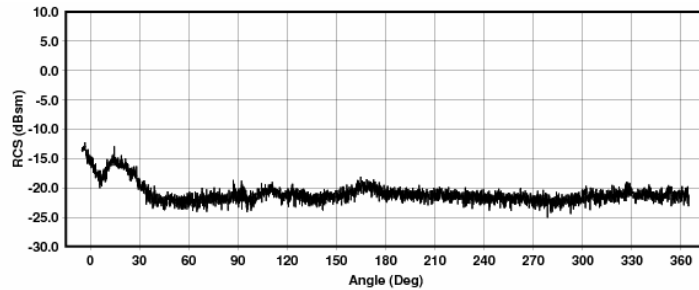
Figure B-27. RCS plots for trial TGT77DB, 15-degree depression, 22.5-degree RPG angle, man kneeling facing aft.



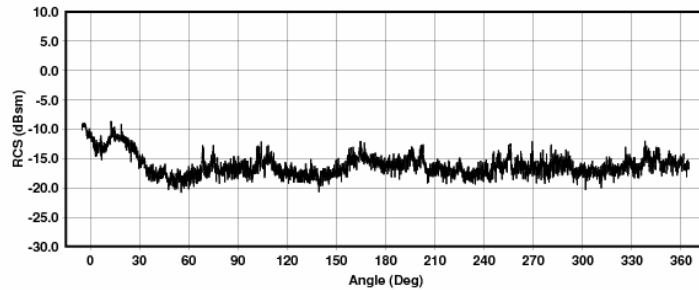
(a) Polarization = TVRV, Mean =  $-14.2$  dBsm, Median =  $-15.0$  dBsm, Standard Deviation =  $11.5$  dBsm



(b) Polarization = TVRH, Mean =  $-20.6$  dBsm, Median =  $-21.2$  dBsm, Standard Deviation =  $13.1$  dBsm

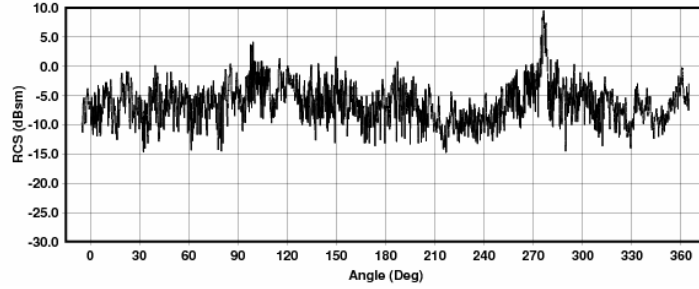


(c) Polarization = THRV, Mean =  $-20.6$  dBsm, Median =  $-21.4$  dBsm, Standard Deviation =  $13.1$  dBsm

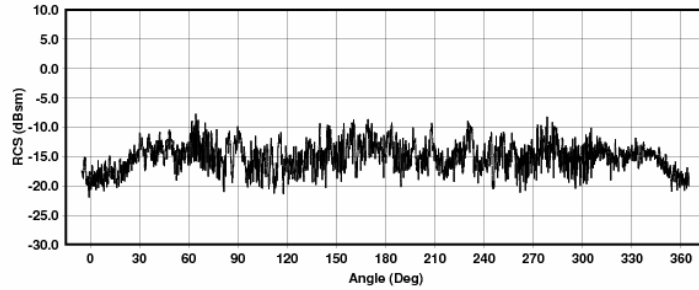


(d) Polarization = THRH, Mean =  $-15.8$  dBsm, Median =  $-16.6$  dBsm, Standard Deviation =  $12.0$  dBsm

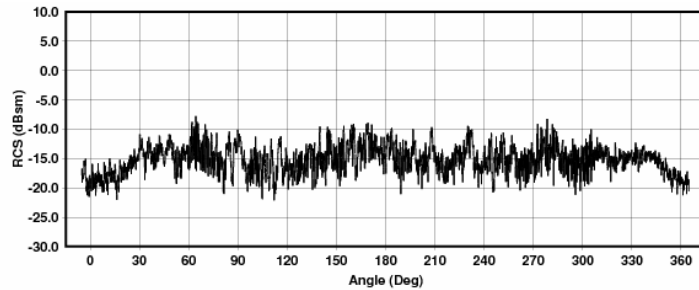
Figure B-28. RCS plots for trial TGT77DC, 15-degree depression, man without RPG kneeling facing aft.



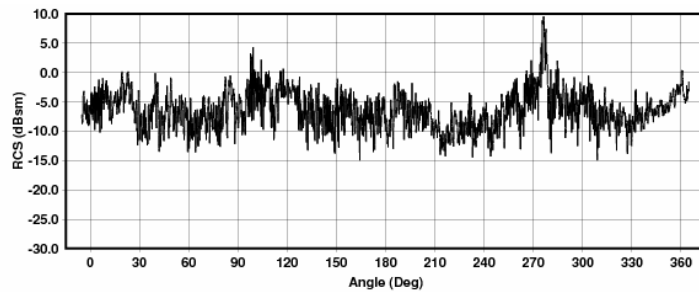
(a) Polarization = TVRV, Mean =  $-5.0$  dBsm, Median =  $-6.4$  dBsm, Standard Deviation =  $7.3$  dBsm



(b) Polarization = TVRH, Mean =  $-14.5$  dBsm, Median =  $-14.8$  dBsm, Standard Deviation =  $11.6$  dBsm



(c) Polarization = THRV, Mean =  $-14.6$  dBsm, Median =  $-15.0$  dBsm, Standard Deviation =  $11.6$  dBsm



(d) Polarization = THRH, Mean =  $-5.1$  dBsm, Median =  $-6.4$  dBsm, Standard Deviation =  $7.4$  dBsm

Figure B-29. RCS plots for trial TGT77DD, 2-degree depression, 45-degree RPG angle, man kneeling facing aft.

---

## Distribution List

---

ADMNSTR  
DEFNS TECHL INFO CTR  
ATTN DTIC-OCP (ELECTRONIC COPY)  
8725 JOHN J KINGMAN RD STE 0944  
FT BELVOIR VA 22060-6218

DARPA  
ATTN IXO S WELBY  
3701 N FAIRFAX DR  
ARLINGTON VA 22203-1714

OFC OF THE SECY OF DEFNS  
ATTN ODDRE (R&AT)  
THE PENTAGON  
WASHINGTON DC 20301-3080

AMSAA  
ATTN AMSRD-AMS-SC F NEWCOMER  
392 HOPKINS RD  
ABERDEEN PROVING GROUND MD  
21005-5701

US ARMY RSRCH DEV AND ENGRG CMND  
ARMAMENT RSRCH DEV AND ENGRG  
CNTR  
ARMAMENT ENGRG AND TECHNLTY CTR  
ATTN AMSRD-AAR-AEF-T J MATTS  
BLDG 305  
ABERDEEN PROVING GROUND MD  
21005-5001

US ARMY TRADOC  
BATTLE LAB INTEGRATION & TECHL  
DIRCTRT  
ATTN ATCD-B  
10 WHISTLER LANE  
FT MONROE VA 23651-5850

SMC/GPA  
2420 VELA WAY STE 1866  
EL SEGUNDO CA 90245-4659

US ARMY ARDEC  
ATTN AMSRD-AAR-AEM-L D VO  
ATTN AMSRD-AAR-AEM S MUSALLI  
BLDG 65S  
PICATINNY NJ 07806-5000

COMMANDING GENERAL  
US ARMY AVN & MIS CMND  
ATTN AMSAM-RD W C MCCORKLE  
REDSTONE ARSENAL AL 35898-5000

US ARMY INFO SYS ENGRG CMND  
ATTN AMSEL-IE-TD F JENIA  
FT HUACHUCA AZ 85613-5300

US ARMY NATL GROUND INTLLGNC CTR  
ATTN IANG-CE-FM/MS404 W NIXON  
2055 BOULDERS RD  
CHARLOTTESVILLE VA 22911-8318

US ARMY SIMULATION TRAIN &  
INSTRMNTN CMND  
ATTN AMSTI-CG M MACEDONIA  
12350 RESEARCH PARKWAY  
ORLANDO FL 32826-3726

US ARMY TACOM  
ATTN AMSTA-AR-AEF-A R HUBAL  
BLDG 65S  
PICATINNY ARSENAL NJ 07806-5000

US GOVERNMENT PRINT OFF  
DEPOSITORY RECEIVING SECTION  
ATTN MAIL STOP IDAD J TATE  
732 NORTH CAPITOL ST., NW  
WASHINGTON DC 20402

SIMTECH  
ATTN S MCFARLIN  
3307 BOB WALLACE AVE #3  
HUNTSVILLE AL 35805

US ARMY RSRCH LAB  
ATTN AMSRD-ARL-SE-RM  
R BENDER  
ATTN AMSRD-ARL-SE-RM  
S STRATTON (3 COPIES)  
ABERDEEN PROVING GROUND MD 21005

US ARMY RSRCH LAB  
ATTN AMSRD-ARL-CI-OK-TP  
TECHL LIB T LANDFRIED (2 COPIES)  
ATTN AMSRD-ARL-SE-RM R TAN  
ABERDEEN PROVING GROUND MD  
21005-5066

DIRECTOR  
US ARMY RSRCH LAB  
ATTN AMSRD-ARL-RO-EV W D BACH  
PO BOX 12211  
RESEARCH TRIANGLE PARK NC 27709

USATC  
ATTN STEAC-TE-AS D LACEY  
ATTN STEAC-TE-AS G ROGERS  
ATTN STEAC-TE-AS H NGUYEN  
ABERDEEN PROVING GROUND MD 21005

US ARMY RSRCH LAB  
ATTN AMSRD-ARL-D J M MILLER  
ATTN AMSRD-ARL-CI-OK-T  
TECHL PUB (2 COPIES)  
ATTN AMSRD-ARL-CI-OK-TL  
TECHL LIB (2 COPIES)  
ATTN AMSRD-ARL-SE-RM E ADLER  
ATTN IMNE-ALC-IMS  
MAIL & RECORDS MGMT  
ATTN AMSRD-AAR-AEP-F  
C VON DER LIPPE  
ADELPHI MD 20783-1197





